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Conifer Establishment Following Prescribed
Broadcast Burning in Larch-fir Forests
A Research Summary Report

Cooperative Research Agreement

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Title of Project

Conifer establishment following prescribed broadcast burning in
Tarch-fir forests --- a research summary report

Herein are attached 3 copies of a report submitted in fulfillment
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Principal Investigator

Ray M. Blake Date 6/18/76

Conifer Establishment Following Prescribed Broadcast
Burning in Larch-Fir Forests--A Research Summary Report

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INTRODUCTION

Fire has played a singularly important role in maintaining several coniferous species as components of western forests. Pioneer species, such as western larch and lodgepole pine, owe their existence in most natural stands of the Northern Rockies to periodic fire. If these species are to be perpetuated after harvest cutting in managed forests, the manager must provide the disturbance to expose mineral soil. On gentle slopes, the manager can choose between mechanical scarification or prescribed burning to achieve disturbance. However, on slopes greater than 35%, prescribed burning is usually used to accomplish site preparation (Schmidt et al. 1976).

Fire was first used for management purposes in the early 1900's, and knowledge of its use has since been developed to the point where it is now a recognized management technique (Roe et al. 1971). A common application of prescribed fire is the broadcast burning of clearcuts for the dual purpose of hazard reduction and seedbed treatment. Too often prescribed burning of clearcuts is done when fuels are wet, and low intensity burns result. Under such conditions, the objective of wildfire hazard reduction is often met, but the objective of site preparation is not. Beaufait et al. (1975) noted that concern is often centered on the fact of burning, rather than on the quality of treatment. That the quality of treatment needs refinement is recognized by managers and researchers alike. To this end, a cooperative study of prescribed burning under a wide range of fuel and weather conditions was jointly conceived by Region One (USFS) and the Intermountain Forest and Range Experiment Station.

The first phase of the study was initiated in 1967 at Miller Creek in northwestern Montana. A similar, second phase was implemented at Newman Ridge on the Montana-Idaho border in 1969. Treatment at both areas was limited to broadcast burning logging slash on clearcuts in the larch-fir type.

The primary objective of this study was to establish criteria by which prescribed burning can be done to best accomplish seedbed preparation, hazard reduction, and other land management objectives. In addition, the study provided a basic design and field layout for studies by related research projects. More specifically, it provided silvicultural research a unique opportunity to study regeneration as related to, and effected by, prescribed burning. Little quantitative data was available to managers relating the effects of variable burning on regeneration. Therefore, the principle objectives of the silviculture study were:

1. To determine the effects of varying intensities of prescribed burning on subsequent coniferous regeneration in larch-fir forests (clearcuts).
2. To develop basic silvicultural and ecological information related to prescribed broadcast burning.

In addition, this project's involvement in the over-all study included consolidating and reducing the above data into ADP formats suitable for incorporation into a data pool available to all cooperators.

Data collection to accomplish objectives of the silviculture project spanned an eight-year period, from 1967-1974. Information gathered included soil temperature and water, root mortality, weather, seed production and dispersal, seedling germination and survival, and natural regeneration and planting data.

STUDY AREA DESCRIPTION

Physiography

The Miller Creek-Martin Creek drainages are located about 20 miles northwest of Whitefish, Montana on the Flathead National Forest (48°31' N. Latitude, 114°43' W. Longitude; Fig. 1). The elevation of the Miller Creek study site varies from 4200 to 5000 feet. Sixty clear-cut units (15 on each cardinal aspect) of approximately 10 acres each were located within the 640 acre study area (Fig. 2). Units were nearly square, about 10 chains on a side, with a 2.5 acre sample subunit established in the center of each (Fig. 3). Each subunit was surrounded by a 2.5 chain wide buffer strip.

Topography at Miller Creek is moderate, with slopes ranging from 10 to 50 percent, and averaging 20 percent. The study site is situated on a deep bed of glacial till, underlain by Belt argillite, quartzite, and siltite (R. C. McConnell unpublished data). Soils fall within the Brown Podzolic Great Soil Group, typified by well-drained sandy and gravelly loams from the Belt formation. These soils belong to the Sherlock series, and feature an unincorporated surface organic horizon 1 to 3 inches thick (Debyle and Packer 1972).

Long, wet winters and short, dry summers characterize the Miller Creek climate. Average annual precipitation is about 25 inches, most of which falls in the form of snow (Debyle and Packer 1972). Rainfall comes primarily in April, May, and June, those months when snowmelt runoff is greatest. Typical summer temperatures range from lows in the 40's (°F)

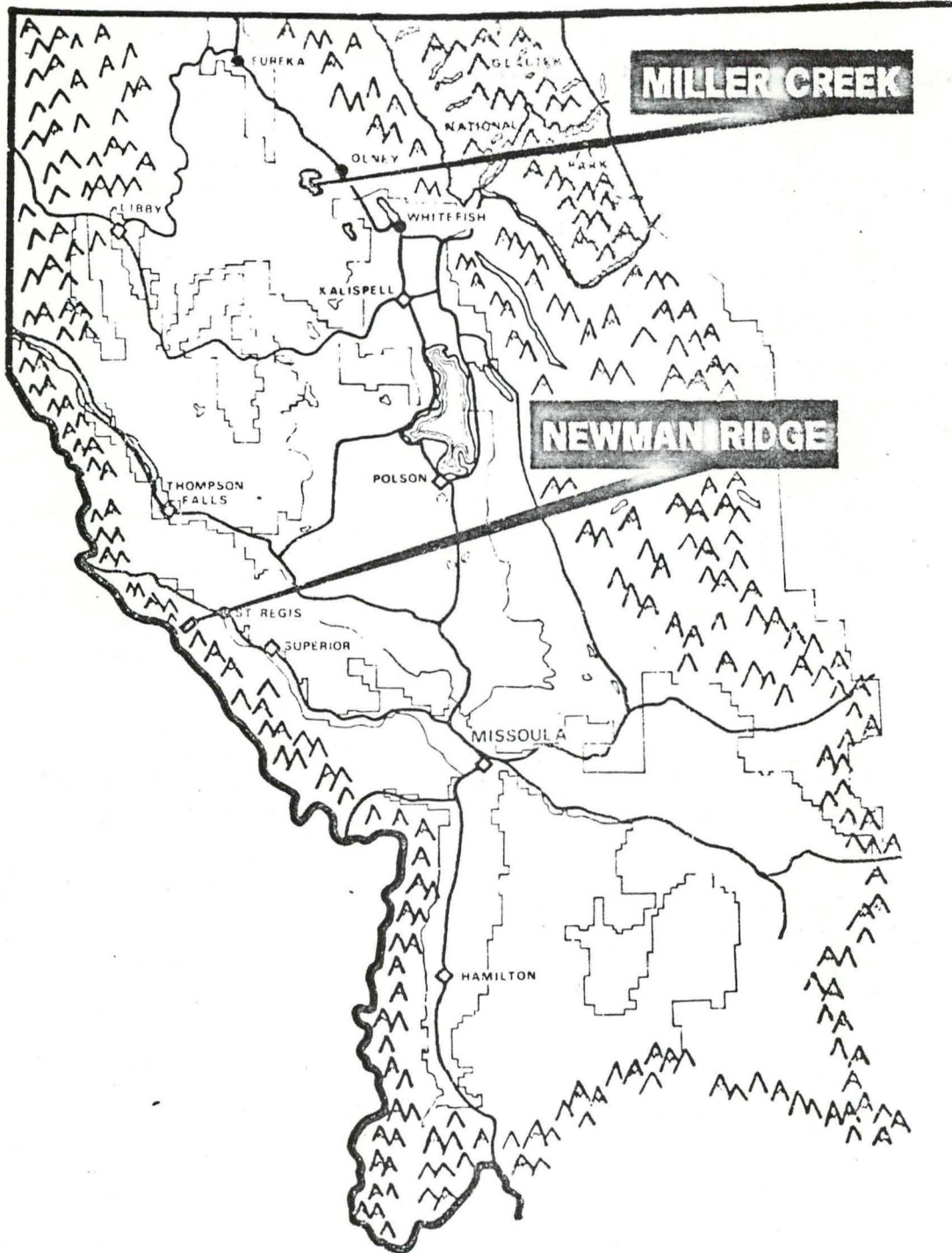


Figure 1.—Study sites on the Flathead and Lolo National Forests in Western Montana.

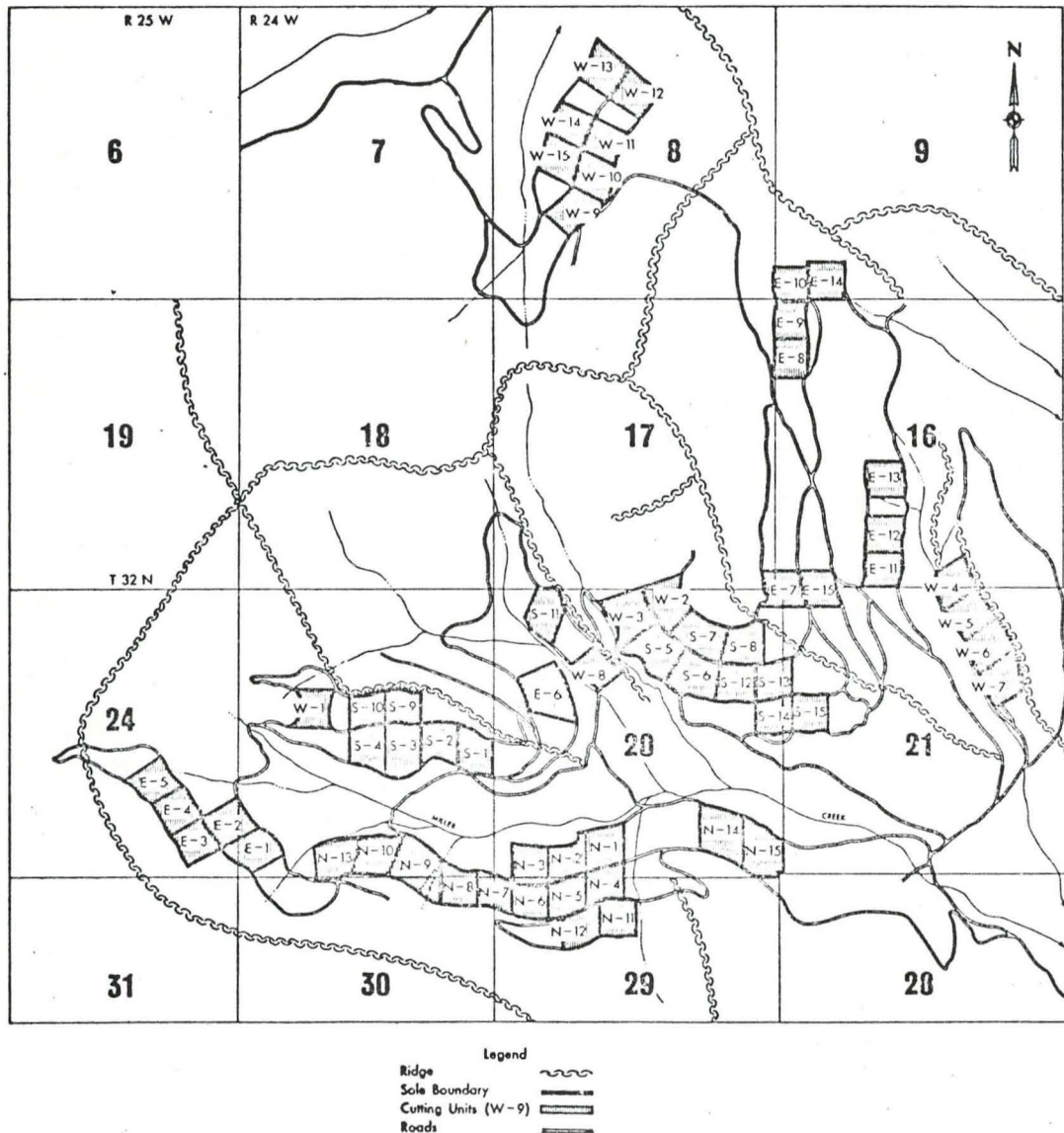


Figure 2.—Miller Creek unit layout.

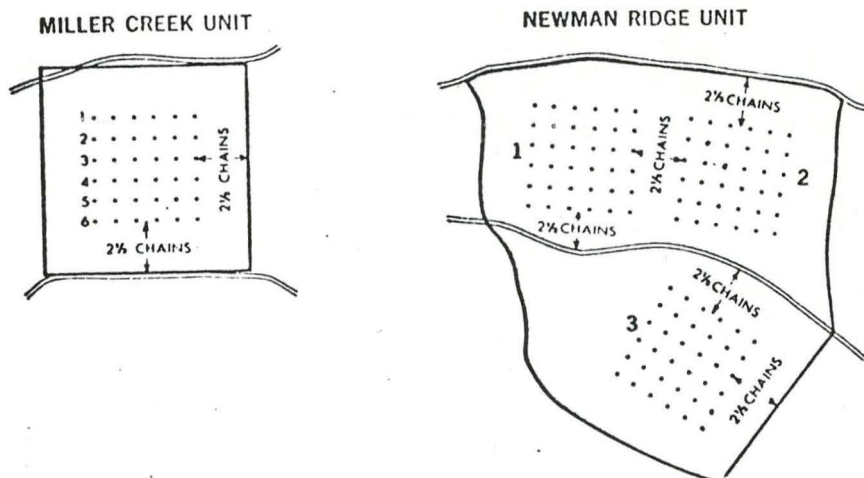


Figure 3.—Subunit layout and sampling point locations on typical units.

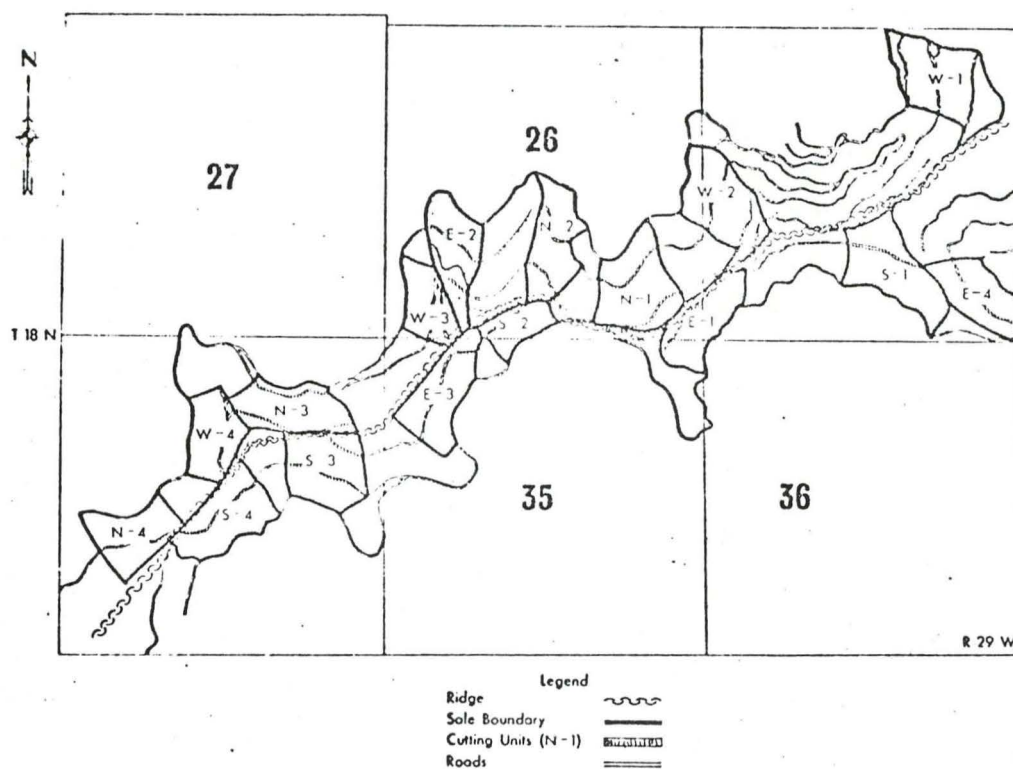


Figure 4.—Newman Ridge with layout.

to highs in the 80's ($^{\circ}\text{F}$), with lows and highs of 30°F and 100°F respectively. No weather data is available for Miller Creek during the winter months.

Newman Ridge is located 8 miles west of St. Regis, Montana on the Lolo National Forest ($47^{\circ}17'$ N. Latitude, $115^{\circ}17'$ W. Longitude; Fig. 1). The 560 acre study site straddles Newman Ridge, which rises between Two Mile Creek to the south and Ward Creek to the north. The study area consisted of 16 clearcut units (4 on each aspect), ranging from 21 to 58 acres (Fig. 4). Unlike Miller Creek, each unit here contained three 2.5 acre subunits (Fig. 3).

Newman Ridge is characterized by steep terrain, with an average slope of 55 percent, and occasional pitches of 100 percent. In contrast to Miller Creek, soils here are underlain by colluvium and weathered bedrock, and lack the coarse fragments which typify glacial till. Soils are loamy, and fall into the Craddock series (Debyle and Packer 1972).

Newman Ridge winters are typically cool, moist and long, and summers short and dry. Approximately 35 inches of precipitation falls annually, about two-thirds of this as snow. Most rainfall is received in the spring months, coinciding with snowmelt runoff. As at Miller Creek, no weather data is available from November through April.

Stand Description

The study sites at Miller Creek and Newman Ridge were selected in the western larch/Douglas-fir forest cover type (Society of American Foresters 1954). The areas provided contrasting topography, soils, and habitat types within a similar cover type.

At Miller Creek, Engelmann spruce and subalpine fir were major associates of western larch and Douglas-fir, along with scattered lodgepole pine. Approximately equal volumes of western larch, Douglas-fir, and Engelmann spruce were removed from the area when logged (Beaufait et al. 1975).

Western larch and Douglas-fir were also major stand components at Newman Ridge, with lodgepole pine, ponderosa pine, and grand fir as common associates. Western white pine, western red cedar, Engelmann spruce, and subalpine fir were also present in the stand, but in minor amounts. The Newman Ridge stand varied in age from 110 to 145 years, with an average age of about 125 years. Average canopy height was about 100 feet. The uncut timber surrounding the cutting units was comprised of 180 trees/ac ($> 6"$ DBH) with a basal area of $180 \text{ ft}^2/\text{ac}$ (Fiedler 1974).

Habitat Types

Miller Creek and Newman Ridge study areas were mapped into ecological units using the habitat-typing system developed by Daubenmire and Daubenmire (1968), as shown in Beaufait et al. (1975). These maps were later revised to be compatible with a recently completed classification scheme for Montana (Pfister et al. 1974).

Miller Creek has a rather uniform, cool, moist environment. Only one habitat type with three phases was represented to any extent at Miller Creek. Most of the study area was classified as an *Abies lasiocarpa*/*Clintonia uniflora* h.t. with three different phases represented: *Menziesia ferruginea* phase on the middle and upper north and

east slopes, *Xerophyllum tenax* phase on the dry south and west aspects, and *Clintonia uniflora* phase on the remaining sites. Cool, moist stream bottoms were classified as *Thuja plicata*/*Clintonia uniflora* h.t. A complete listing of Miller Creek units by habitat type was made by Shearer (1975).

In contrast, five distinct habitat types, from warm and dry (*Pseudotsuga menziesii*/*Xerophyllum tenax* h.t. *Vaccinium globulare* phase) to cool and moist (*Thuja plicata*/*Clintonia uniflora* h.t. *Menziesia ferruginea* phase) were identified on study plots at Newman Ridge. This variety of types was reflected in the broad vegetal diversity which occurred across the Newman Ridge study area. The five habitat types represented were: *Abies grandis*/*Clintonia uniflora* h.t. on concave east, northwest, and protected south-facing slopes; *Abies grandis*/*Xerophyllum tenax* h.t. on upper west-facing slopes; *Thuja plicata*/*Clintonia uniflora* h.t. *Menziesia ferruginea* phase on concave north and northeast aspects; *Pseudotsuga menziesii*/*Xerophyllum tenax* h.t. *Vaccinium globulare* phase on upper south-facing slopes; and *Pseudotsuga menziesii*/*Physocarpus malvaceus* h.t. *Physocarpus malvaceus* phase on convex west slopes. All subunits within the eight units studied intensively were classified under one of these habitat types (Table 1). In addition, small amounts of two other habitat types were noted: *Abies lasiocarpa*/*Clintonia uniflora* h.t. *Menziesia ferruginea* phase on north slopes along the ridge lines; and *Abies lasiocarpa*/*Xerophyllum tenax* h.t. *Vaccinium globulare* phase on south slopes along the ridge line. However, no study plots fell on either of these habitat types.

Table 1.—Habitat type by subunit for each of the eight units studied intensively at Newman Ridge, Lolo N.F.

Habitat Type ¹				
Unit	:	Subunit 1	Subunit 2	Subunit 3
N-1		A/C	T/C	T/C
E-1		A/X	A/X	A/X
S-1		A/X	P/X	P/X
W-1		A/X	A/X	P/P
N-3		T/C	T/C	T/C
E-3		A/C	A/C	A/C
S-3		P/X	P/X	A/X
W-3		A/X	A/X	A/X

¹Classified by Robert D. Pfister:

PX - *Pseudotsuga menziesii*/*Xerophyllum tenax* h.t. *Vaccinium globulare* phase

PP - *Pseudotsuga menziesii*/*Physocarpus malvaceus* h.t. *Physocarpus malvaceus* phase

AX - *Abies grandis*/*Xerophyllum tenax* h.t.

AC - *Abies grandis*/*Clintonia uniflora* h.t.

TC - *Thuja plicata*/*Clintonia uniflora* h.t. *Menziesia ferruginea* phase

PROCEDURES

Study Design

The primary goal of the fire research team was to relate burn accomplishment to fuel loading, fuel moisture, and atmospheric conditions at time of burning. A schedule to accomplish this task called for an equal number of burns, in similar fuel loadings, on all aspects, in the spring, summer, and autumn for two years (1967 and 1968) at Miller Creek and one year (1969) at Newman Ridge (Beaufait et al. 1975). This design and layout gave other projects the opportunity to conduct varied but complementary studies within the framework of a larger, overall study. The ideal of complete orthogonality, as laid out above, was not achieved. A wildfire on August 23, 1967 at Miller Creek burned several south, east and west-facing units, creating an imbalance in the study design. Concern over possible "blow-ups" resulted in further compromising the original design, as units with heavy fuel loads were burned under wetter conditions than those with light loads.

Silviculture Study Design

Soil Water

Soil water changes related to prescribed burning were determined from samples taken at six points on each prescribed burn unit (See Appendix). At Miller Creek, with only one subunit per unit, one sample point was selected randomly from each of the six rows comprising the 36 sample-point grid. Each Newman Ridge unit contained three subunits, so

sampling here was accomplished by selecting one sample point each in rows 1 and 2 of subunit 1, one each in rows 3 and 4 of subunit 2, and one each in rows 5 and 6 of subunit 3. Preburn samples were usually taken the afternoon of, and postburn samples the morning after each prescribed burn. Preburn and postburn samples were taken 16 inches apart, and at four soil levels: 0-0.5, 0.5-1, 1-2.25, and 2.25-4 inches. Percent soil water was determined gravimetrically using the following equation:

$$\% \text{H}_2\text{O} = \frac{\text{wet soil weight} - \text{dry soil weight}}{\text{dry soil weight}} \times 100$$

Samples were tested for percent over-dry weight of soil with rock, and of soil without rock (rock > 2mm diameter removed). In addition, samples were taken periodically in unburned timber, burned timber, and unburned and slashed conditions for several years following burning of the units.

Soil Temperature

Temperatures reached during burning at depths to 6 inches in the soil were recorded at 36 sample points in each prescribed burned unit (See Appendix). At Miller Creek, with only one subunit per unit, all 36 points in the single subunit were sampled. At Newman Ridge, with three subunits per unit, all points in rows 1 and 2 of subunit 1, rows 3 and 4 of subunit 2, and rows 5 and 6 of subunit 3 were sampled.

Asbestos strips treated with Tempilaq (a temperature-sensitive material with melting points ranging from 113° to 1000°F) were used to record maximum soil temperatures (Shearer 1975). Prior to burning, treated strips were inserted vertically into the soil so the top edge was even with the duff-soil interface. The day following burning, strips were removed and the depth of melt measured for each temperature

category. This measurement reflected the maximum depth at which the threshold melt temperature was reached at any time during the burn.

Duration of temperature maximums was recorded at two selected points during several prescribed burns. Thermocouples were inserted horizontally into the soil at 0.2, 0.4, 0.8, and 1.6 inch depths. Chromal/alumel thermocouple probes were used at the 0.2 inch depth, and iron/constantan probes at all other depths.

Root Mortality

Broadcast-burn related root mortality of non-coniferous vegetation was measured at the same 6 points within each unit as soil water. To accomplish this, a vertical soil face about 5 inches deep and 10 inches wide was exposed, against which was pressed a 4 inch by 8 inch template. A chemical test developed by Hare (1965) was used to test whether exposed roots appearing within the template boundaries were living or dead. Roots were first sprayed with 1 percent orthotolidine solution, followed immediately by a second spraying with a 3 percent hydrogen peroxide solution. These solutions react with peroxidase, an enzyme found in living cells, to form a blue product. Dead roots lack this enzyme, hence exhibit no color change with spraying. Root mortality counts were made several days prior to broadcast burning, and again about 2 weeks after.

Duff Reduction

Duff reduction was calculated from measurements taken at each of the 36 Tempil strip locations on a unit (See Appendix). Two measurements were taken adjacent to the spike marking each Tempil strip; one the day

before broadcast burning, and a second the day after burning. The difference between the two measurements was the amount of duff consumed by the fire.

Seedbed Condition

At Miller Creek, postfire estimates of seedbed condition were made on circular, milacre plots at each of the 36 points within the single subunit, and at 1 chain intervals along row and column continuation lines to the unit edge. Estimates were made on the same plots and at the same time as the natural regeneration counts. Eight seedbed categories were recognized: (1) burnt mineral soil, (2) mineral soil, (3) unburned duff, (4) scorched duff, (5) rotten wood, (6) logs, (7) rock, and (8) unburned. Miller Creek units on which seedbed estimates were made are listed in the Appendix.

Seedbed estimates at Newman Ridge were made by scanning 10' by 10' quadrats for percent coverage of four types of seedbed: (1) bare soil, (2) duff (>0.5 inch), (3) scarified by logging, and (4) no seedbed (logs, rocks, or stumps). Quadrats were located at 2 chain intervals in a grid system, and estimated in conjunction with the placement of seed traps at the same locations. Units sampled for seedbed are listed in the Appendix.

Seed Production and Dispersal

Seed crops of major species at Newman Ridge were estimated the summers of 1969-1974 using a sequential sampling technique developed by Roe (1966). By this method, selected limbs of sample trees were scanned with binoculars and the strobili counted. Counts were compared to the

critical values derived by Roe to determine whether the crop would be classified good, medium, or poor. Seed production estimates were taken on 23 western larch and 19 Douglas-fir trees in July and August preceding each year's seedfall.

Seed dispersal at Newman Ridge was estimated for the years 1969-1974 from seeds caught in traps placed on 8 clearcut units. Collections were made from two units facing each cardinal direction (N-1, N-3, E-1, E-3, S-1, S-3, W-1, W-3). From 14 to 36 rectangular, 0.1 milacre seed traps were systematically spaced at 100' intervals within each opening. A total of 246 seed traps were placed on the eight clearcut units. Late fall and early summer collections were made of each seed crop over the 6-year period.

Seed dispersal in the timber was sampled by 2 seed traps placed 2 chains apart and 1 chain in the seedwall on each timbered side of all sample units except N-1. Unit N-1 was not sampled because a wildfire in 1969 destroyed the surrounding seedwall. A total of 46 traps was placed in the timber surrounding the 7 other units.

Large rectangular seed collectors (4' by 8') were placed within the timber in areas of high dispersal potential to determine timing of seedfall. Three collectors were placed in the timber surrounding S-3, and one in the timber adjacent to unit N-3. Collectors were checked for seed at 10 to 15 minute intervals during prime dispersal hours of the 1969 seedfall season.

Seedling Establishment

Germination of western larch, Engelmann spruce, and Douglas-fir seed sown on two seedbed conditions was studied at Miller Creek from 1968-1971. Germination plots (2' by 6') were established on four units in 1967, and on nine additional units in 1968. One or more plots on each unit were established on seedbed with no duff remaining (0.0" duff), and an equal number on seedbed with 0.5" duff. Each of the 2' by 6' plots was divided into three subplots with dimensions of 2' by 2'. Western larch, Engelmann spruce, and Douglas-fir seed were sown separately on these subplots, as assigned by random selection. Each subplot was broadcast sown in mid-October with 500 green-dyed seeds of the appropriate species. Plots were first examined for germination when they became snow-free in the spring, and at about weekly intervals thereafter until no new germination was noted. Germinants for each week were marked with toothpicks of a different color. Regeneration from previous weeks was also examined, and dead seedlings tallied for cause of mortality.

Two extraneous factors prompted the screening of half the germination plots with hardware cloth in the fall of 1968, and all plots in the fall of 1969 and 1970, so that other mortality factors could be evaluated. Seed sown the first fall after burning (1967) on unscreened plots on burned seedbed suffered heavy losses to rodent depredation. The following spring (1968) the peak germination of remaining western larch and Douglas-fir seed coincided with the migration and feeding of the dark-eyed junco, Junco oregonus (Townsend), resulting in the loss of nearly all seedlings that had not shed their seedcoats. This combination of events manifested the need for preventing biotic predation of seeds

and seedlings, if other mortality factors were to be studied in detail. Screening plots with hardware cloth was selected as the solution to this problem.

At Newman Ridge, germination of western larch, lodgepole pine, and Douglas-fir seed sown on three different seedbed conditions was studied from 1970-1972. Germination was studied on five units (N-1, E-1, S-1, W-1, and E-3) in the spring of 1970 and 1971, and on seven units (N-1, E-1, S-1, W-1, E-3, S-3, and W-3) in the spring of 1972. Ten 1 ft² circular plots were established on three different seedbed conditions (0.0", <0.5", >0.5" duff depth) on each unit. One hundred sound seeds each of western larch, lodgepole pine, and Douglas-fir were fall sown on each 0.565' radius plot. In addition, seed of ponderosa pine, grand fir, and Engelmann spruce were also sown on units where these species grew previously. The reason for the small plots used here, as opposed to the 2' by 2' subplots used at Miller Creek, was to fit a greater number of plots into a limited amount of available seedbed.

All germination plots at Newman Ridge were screened each year from the time seeds were sown in the fall until most seedcoats were shed the following spring.

Artificial seeding plots were used to simulate natural seeding for two reasons: (1) natural seed sources could not be relied on to disperse sufficient seed on the plots for a detailed study of germination, and (2) number and species composition of seeds were known.

Natural Regeneration

Natural regeneration counts at Miller Creek were taken on the same milacre plots and the same units (See Appendix) as the seedbed evaluations. Because of the large number of units surveyed at Miller Creek, plots were checked only once, either in the fall of 1973 or the spring of 1974. Plots were tallied for: (1) number of seedlings of each species (WL, DF, ES, or other) and age (2, 3, 4, or 5 years) of seedlings, (2) type of seedbed (see seedbed section), and (3) amount (0-25, 25-50, 50-75 or 75-100%) and type (grass, forbs, herbs, or moss) of competing vegetation.

At Newman Ridge, natural regeneration was counted on milacre plots established at or near each of the 36 points within a unit on the closest burned mineral soil seedbed. When seedbed that was either scarified or had >0.5 inch duff remaining was found within 20 feet of a point, plots were also established on these seedbeds. Because Newman Ridge had fewer units to sample than Miller Creek (7 vs. 34), complete natural regeneration surveys were taken here in the fall of 1972, and in the spring of 1973 and 1974.

Planting Stock

Beginning in 1968 at Miller Creek, 75 seedlings each of 1-0 western larch, 2-0 Engelmann spruce, and 2-0 Douglas-fir were cluster-planted at 1' spacing on E-7 and W-7. An additional 150 seedlings each were similarly planted on W-1 and N-11, for a total of 1350 on the four units (Table 2). Because of the tight spacing, no vigor examinations were made after this planting.

Table 2.—Number of seedlings each of western larch, Engelmann spruce and Douglas-fir planted by unit and year at Miller Creek

1968		:	1969		:	1970-1973	
Unit	Number	:	Unit	Number	:	Unit	Number
N-11	150		N-11	100		N-8,9,11,13	50
			N-8,9,13	50			
E-7	75		E-7	100		E-3,5,7,10	50
			E-3,5,10	50			
W-1	150		W-1	100		W-1,7,8,10,12	50
W-7	75		W-7	100			
			W-8,10,12	50			
Total	450			850			650

Starting in 1969, 50 seedlings each of 1-0 western larch, 2-0 Engelmann spruce, and 2-0 Douglas-fir were planted on nine units, and 300 of each on four other units (Table 2). Seedlings were spring-planted at a spacing of 5' by 5' using power augers. Planting by this method was repeated annually through 1973 until competition made it difficult to find enough suitable seedbed for another year's planting. All stock planted from 1969-1973 was examined and tallied for vigor in 1974.

Five Newman Ridge units were first planted the spring of 1970 with approximately 100 seedlings each of western larch, Douglas-fir, and lodgepole pine, and annually after that through 1975. An equal number of ponderosa pine, Engelmann spruce, and grand fir seedlings were planted on units where they grew previously. Five species were planted on two units (E-3, W-3), with four species being planted on all other units, as follows:

Unit	1970						:	1971						:	1972					
	WL	DF	ES	GF	PP	LP		WL	DF	ES	GF	PP	LP		WL	DF	ES	GF	PP	LP
N-1	X	X		X		X		X	X		X				X	X		X		
E-1	X	X		X		X		X	X		X				X	X		X	X	
S-1	X	X			X	X		X	X			X			X	X				
W-1	X	X			X	X		X	X			X			X	X				
E-3	X	X	X	X		X									X	X	X	X	X	
S-3															X	X				X
W-3								X	X		X	X	X							

All planting at Newman Ridge was done with power augers at 9' by 9' spacing. Survival and vigor estimates for only the first three years of planting (1970-1972) were available for this paper.

Weather Parameters

Temperature, relative humidity, wind speed and wind direction were measured at three Newman Ridge weather stations from 1969-1974. One station was installed in the center of a south-facing clearcut (S-3), one in the middle of a north-facing unit (N-3), and one on the ridge between. Two types of weather recording instruments were used at each location. Battery-powered mechanical stations (MRI) recorded wind speed and direction, and supplemental temperature measurements. Hygrothermographs placed in standard U.S. Weather Bureau instrument enclosures provided relative humidity and temperature records at each location. All three stations were operative from June, when locations first became accessible, to October, when winter weather prompted their removal.

RESULTS

Preburn and Postburn Seedbed Conditions

Soil Water

Gravimetric samples taken periodically on each aspect at Miller Creek in 1970, 1971, and 1974 showed May to be the month with greatest soil water on all aspects, and August the least. That August was the driest month, from a soil water standpoint, was further supported by the fact that greatest seedling mortality due to drought also occurred in August. The months of June, July, and September fell between the wet month of May and the dry month of August in the soil water rankings: May > June > July > September > August. This order held for all aspects and all years. Rankings were based on the average percent soil water at four depths for the period May-September of each year.

Gravimetric soil water samples taken at Newman Ridge during the 1970-1972 field seasons, and again in 1974, yielded rankings identical to those at Miller Creek on all aspects except south. On that aspect September was a drier month than August. With the exception of this reversal, ranking of all other months remained the same. Soil water was sampled in October only one year (1972), and that year's sample ranked October between June and July on all aspects.

Soil water was also evaluated by aspect, and at Miller Creek was found to be highest on the north aspect, followed by the east, west, and south aspects, in that order. These relative rankings held for all months (May-September) of all years.

Newman Ridge soil water rankings by aspect were in the order: north—east—south—west for the years 1970, 1971, and 1972, and north—south—east—west in 1974. The north aspect consistently had the greatest soil water, and the west the least, with little real difference between the east and south aspects.

Samples taken from Newman Ridge units S-3 and N-3 showed soil water in the upper four inches of soil to be significantly higher than in the adjacent timber. Samples were drawn from upper, mid, and lower slope positions in mid to latter July in 1969, 1970, 1971, 1972, and 1974. Both units were logged in June, 1969. The difference in soil water contents between clearcut and timber was greatest the year of logging, and disappeared on both aspects by the fifth year (Table 3). Furthermore, though the trend was similar on both slopes, differences in soil water between clearcut and timber were somewhat greater on the north aspect than the south. The disparity in soil water contents between clearcut and timber lasted about three years after treatment on the south aspect, and four to five years on the north aspect. Similar comparisons of soil water on east and west aspects could not be made as complete samples were not taken on these slopes.

Soil Temperature—Duff Reduction

Soil temperature maximums reached at or near the soil surface during prescribed burning were significantly lower at Miller Creek than Newman Ridge. At Miller Creek, over 75 percent of the sample points reached maximum soil temperatures between 138°F and 163°F, while at Newman Ridge maximums ranged much higher, with 75 percent between 200°F and 400°F. That soil temperature maximums were higher at Newman Ridge could be attributed

Table 3.—Comparison of soil water in the upper four inches of soil between units S-3 and N-3 and the adjacent timber for five years after treatment, Newman Ridge, Lolo National Forest

Year	Soil Depth (inches)	(S-3)		Soil Water		(N-3)	
		Open	Timber	Open- Timber	Open	Timber	Open- Timber
1969	0.0-0.5	34	13	+21	49	9	+40
	0.5-1.0	28	13	+15	42	11	+31
	1.0-2.25	24	11	+13	39	10	+29
	2.25-4.0	24	10	+14	45	11	+34
1970	0.0-0.5	38	23	+15	48	23	+25
	0.5-1.0	26	20	+ 6	42	22	+20
	1.0-2.25	29	16	+13	43	19	+24
	2.25-4.0	25	16	+ 9	34	16	+18
1971	0.0-0.5	41	39	+ 2	57	36	+21
	0.5-1.0	37	33	+ 4	47	38	+ 9
	1.0-2.25	38	23	+15	43	35	+ 8
	2.25-4.0	39	28	+11	47	33	+14
1972	0.0-0.5	13	22	- 9	34	27	+ 7
	0.5-1.0	12	21	- 9	44	31	+13
	1.0-2.25	10	10	0	35	18	+17
	2.25-4.0	11	9	+ 2	33	20	+13
1974	0.0-0.5	2	7	- 5	10	13	- 3
	0.5-1.0	4	8	- 4	11	14	- 3
	1.0-2.25	5	8	- 3	9	14	- 5
	2.25-4.0	7	9	- 2	14	24	-10

to the lower average soil water and fuel moisture conditions which, with few exceptions, existed there. Preburn fuel moisture, averaged for all units, was only 19 percent at Newman Ridge, compared to 48 percent at Miller Creek. Average moisture content of fuel components (duff, litter, and slash) was calculated for both areas from data presented by Beaufait et al. (1975).

The significant difference in soil temperature maximums between Miller Creek and Newman Ridge was reflected in percent duff reduction at the two areas. Average duff reduction at Miller Creek ranged from 36 percent at 125°F maximum soil temperature, to only 70 percent at 400°F (Fig. 5). At Newman Ridge, in contrast, average duff reduction varied from 44 percent at 113°F soil temperature, up to 99 percent at 500°F (Fig. 6).

Figure 5.—Average percent duff reduction at Miller Creek
by maximum tempil melt category.

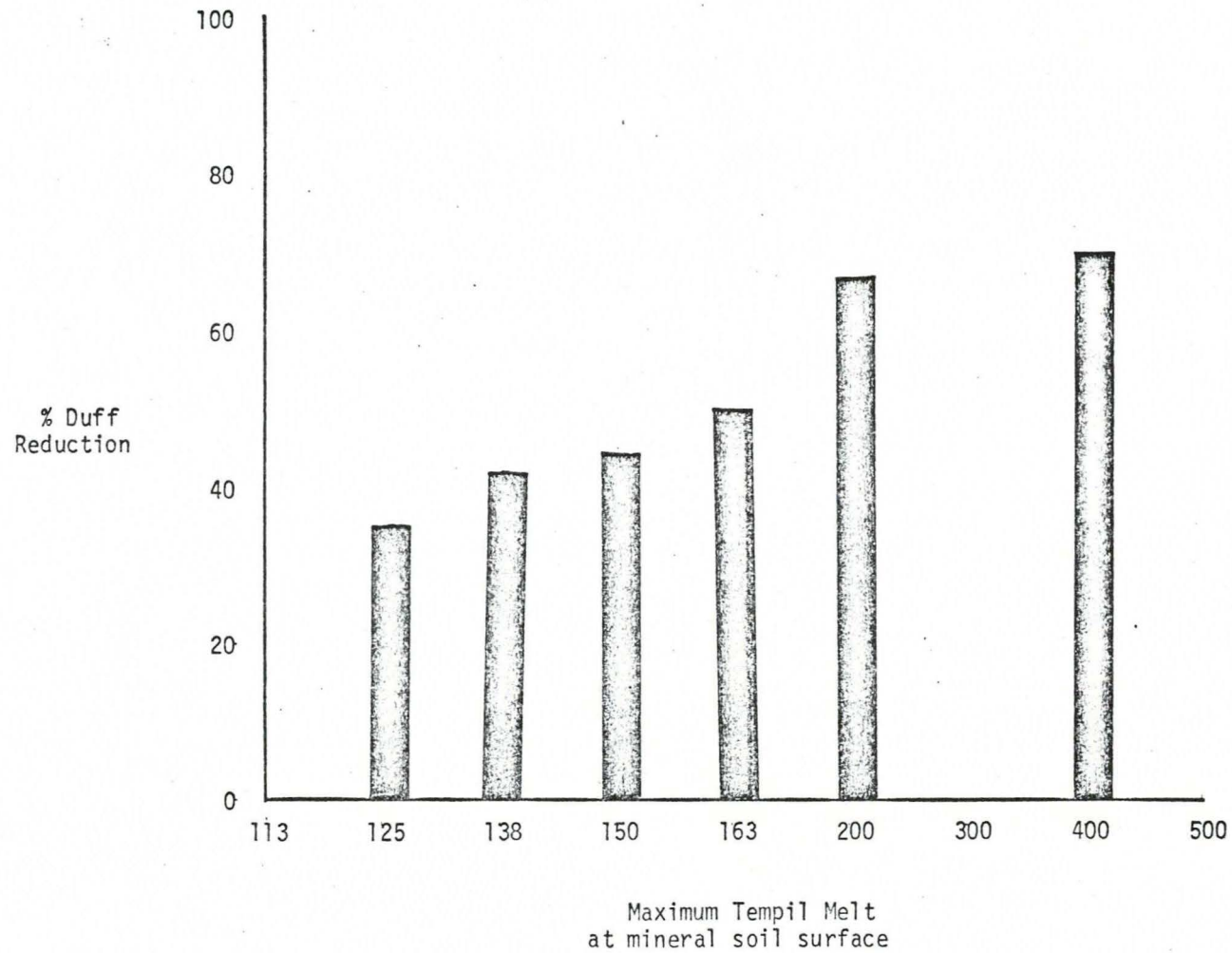
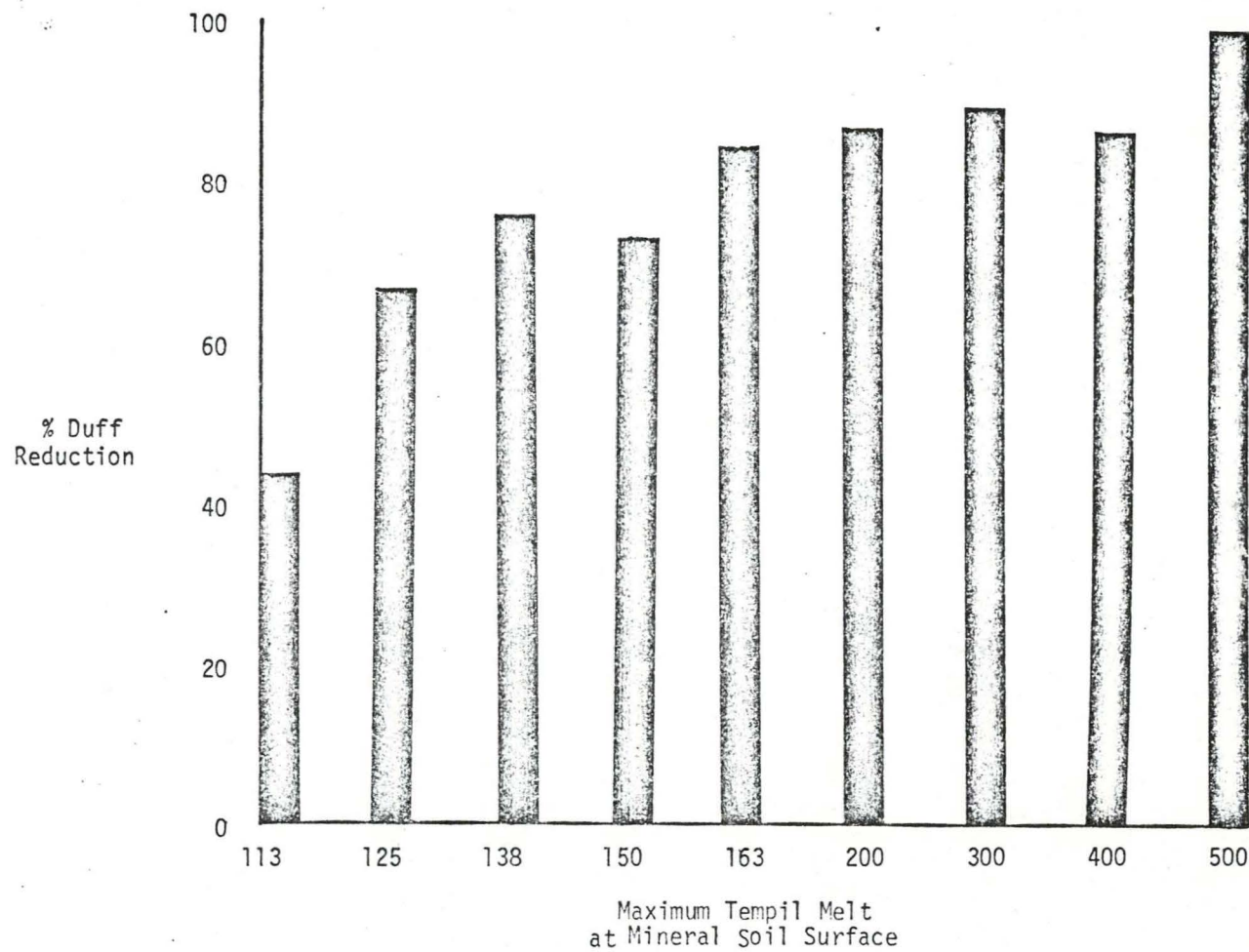


Figure 6.—Average percent duff reduction at Newman Ridge
by maximum tempil melt category.



Competing Vegetation

Coverage. A survey of understory vegetation in 1973 at Miller Creek showed only the grass component to vary significantly between habitat types. This survey was conducted five years after burning in conjunction with, and on the same plots as, the natural regeneration survey. When each habitat type was evaluated for percent plots with presence of grass, forbs, or shrubs, results were as follows:

Habitat Type	Grass	Forbs percent	Shrubs
A/C-X	67	79	76
A/C-C	31	88	92
A/C-M	5	72	94

Results reflect understory vegetation conditions as they existed in 1973 only. They do not warrant speculation of understory development prior to 1973, or projections of vegetational change after that time.

It is noteworthy that the ranking of habitat types by percent plots with grass presence ($A/C-X > A/C-C > A/C-M$) is reverse in order to percent stocked plots by habitat type ($A/C-M > A/C-C > A/C-X$). Larsen (1916) recognized grass as a deterrent to larch regeneration in the early 1900's. Spruce regeneration in Utah, Wyoming, and Idaho was found to vary inversely with grass coverage up to 100 percent (Fiedler, C. E. and W. C. Schmidt unpublished data). It is probable that at least part of the stocking problem on the *Abies lasiocarpa*/*Clintonia* h.t. Xerophyllum phase was due to the considerable number of plots with grass presence (67 percent).

Root mortality. Root mortality of non-coniferous vegetation at Miller Creek was found to vary from 0 to 100 percent according to the amount of water in the soil and the energy released from prescribed burning (Shearer 1975). Shearer found that burning in the spring when soil water was high, regardless of intensity, caused root mortality in the surface half inch only, if at all. Low intensity fires over dry soils caused considerable mortality within 1 to 2 inches of the soil surface, but had little effect below that level. Only the combination of a high intensity fire over dry soils killed most roots in the upper 4 inches of soil.

At Newman Ridge, highly variable root mortality results from prescribed burns of similar intensity precluded development of relationships with soil water and energy release. High intensity burns and "cool" burns caused considerable and little root mortality, respectively, but the majority of moderate burns had highly inconsistent effects. Newman Ridge soils had a high complement of rock, which may explain the disparity in root mortality which often resulted on units burned under similar conditions.

Regeneration on Prescribed Burn Seedbeds

Natural

Seed production. Seed crop estimates for the years 1969-1974 predicted 2 good crops, 2 medium-poor crops, and 2 failures. Actual seed crops were rated as follows: 1 good, 2 poor, and 3 failures. Significant

differences between predicted and actual larch seed production occurred in 1970, 1973, and 1974, as shown below:

		1969	1970	1971	1972	1973	1974
Western larch	Predicted	F	M	G	F	G	G
	Actual	F	P	G	F	F	P

Douglas- fir	Predicted	F	P	G	F	F	G
	Actual	F	F	G	F	F	P

Disparities were probably due to difficulties encountered by observers in discerning color differences between new and old cones under less-than-optimum lighting conditions.

Cone crop estimates were also made on several grand fir, ponderosa pine, Engelmann spruce, and western white pine trees each year. Though only a few trees of each were sampled, the high degree of similarity between estimated and actual seed crops indicate that seed production by these species may be reliably predicted by Roe's (1966) technique.

Seed dispersal. Seed collection results from 1969-1974 at Newman Ridge showed that total sound seed dispersal varied from 44,000 per acre in the zone 0-200 feet from the seedwall, to 10,000 per acre in the zone 600-800 feet distant from the timber (Table 4). Over the six-year study period, only 1971 could be considered a good seed year. Percent soundness of seed was also higher in 1971 than any other year. The total number of sound seeds dispersed on the cutting units leveled off

at about 300 feet from the seedwall (Fig. 7). Dispersal continued at a rather low but uniform rate up to 800 feet from the timber.

Table 4.—Total seed dispersed during the 6-year period
1969-1974

Distance from Seedwall	Total sds/ac	% of Total	Sound sds/ac	% of Total
0-200'	170,011	52	43,591	52
200-400'	76,601	23	18,850	23
400-600'	48,550	15	10,690	13
600-800'	34,613	10	9,999	12

Clearcut/timber seedfall ratios (ratio = average number of seeds/acre dispersed within the clearcut $\div$ the average number/acre dispersed in the timber) developed for five Newman Ridge species varied from a low of 9 percent for western larch to a high of 40 percent for Engelmann spruce (Fig. 8). Some of the apparent discrepancy between ratios of these similarly light-seeded species ($\sim 135,000$ seeds/lb) can probably be attributed to differences in distribution of seed source. Western larch was well distributed throughout the seedwall surrounding the units. Spruce, on the other hand, appeared only occasionally in the stand, and then in locations especially favorable for dispersal by either slope or prevailing winds. The low ratio of clearcut/timber seedfall for ponderosa pine, grand fir, and Douglas-fir would be expected for these heavy-seeded species ($\sim 12,000$, $19,000$, and $40,000$ seeds/lb, respectively).

Seed dispersal was greatest on south-facing clearcuts, followed by west, east, and north units in that order. This ranking is understandable

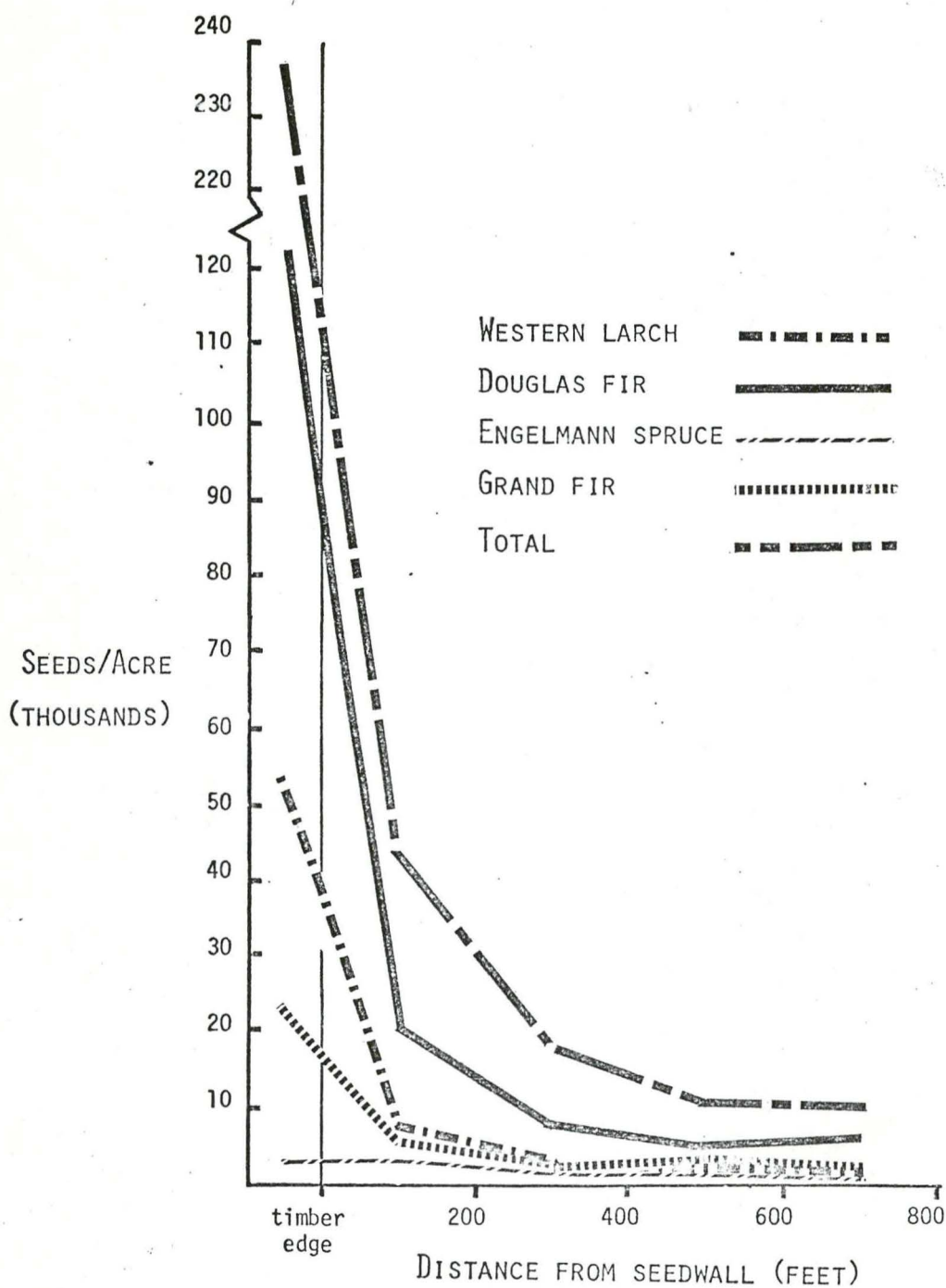
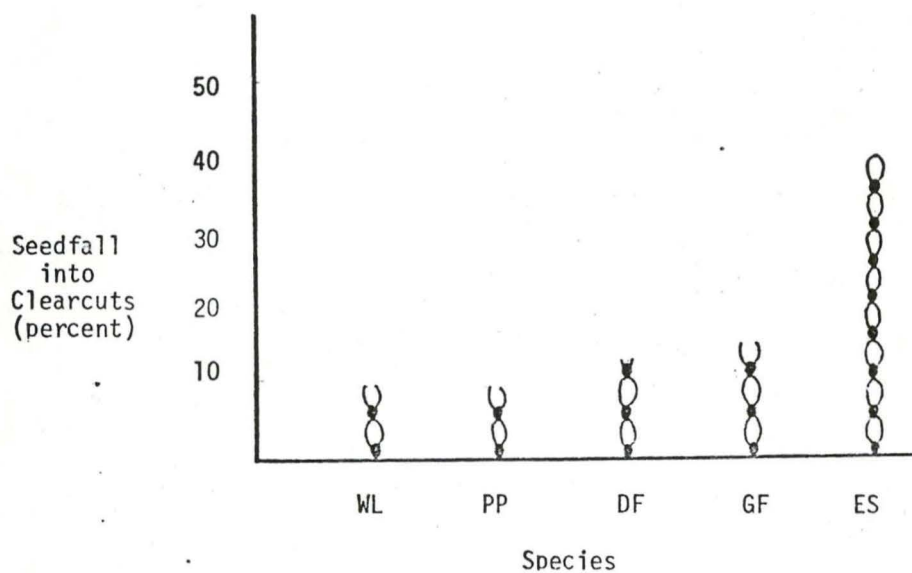


Figure 7.—Average number of sound seed per acre dispersed on eight clearcut blocks at Newman Ridge by species and distance from seed source (1969-1974).

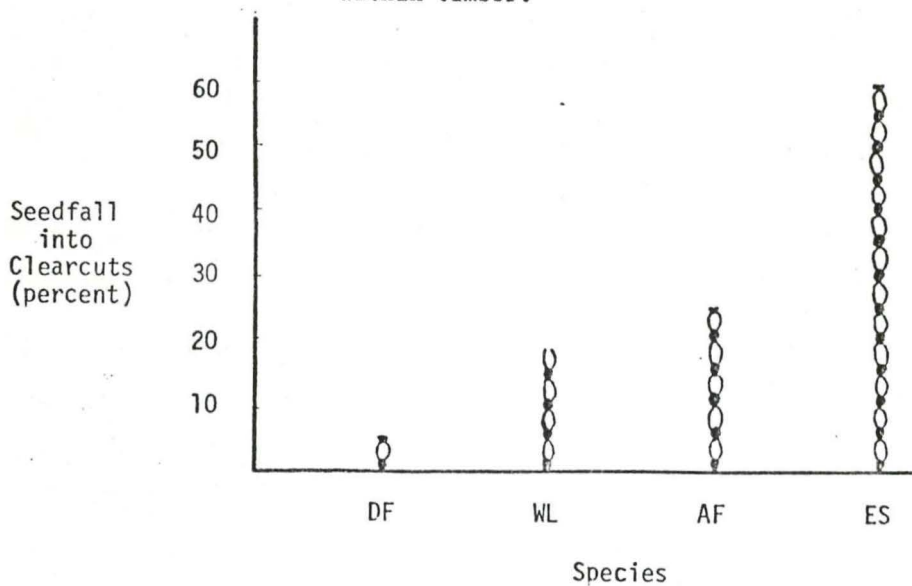
NEWMAN RIDGE

Figure 8.—Seedfall into clearcuts as percent of seedfall within timber.



MILLER CREEK

Figure 9.—Seedfall into clearcuts as percent of seedfall within timber.



if it parallels the hypothetical ranking of thermal wind velocity by aspect, i.e. south > west > east > north. A detailed study of wind behavior on Newman Ridge during the 1969 seedfall season provided a rationale for the considerably greater seed dispersal on the south aspect than the north. During the prime seedfall hours of noon to 6:00 p.m., when temperatures were highest and relative humidities lowest, average wind velocities by hour were considerably higher on the south aspect than the north. Velocities ranged from 1.5 mph to nearly 2 mph greater on the south aspect during this period. Similar wind measurements taken throughout the 1971 seedfall season showed even greater disparity between slopes, with average differences of 3.5 mph to nearly 5 mph during the prime dispersal hours.

Dispersal ratios were also developed for several species at Miller Creek from the single seed collection taken there in 1971. Western larch and Engelmann spruce again had significantly different dispersal ratios, 19 percent vs. 61 percent (Fig. 9). Because of the disparity between ratios of these species at both areas, dispersal ratios for 1952 were also calculated from Squillace's (1954) one-year study of spruce dispersal at Falls Creek in Northwestern Montana, and Shearer's 6-year results from the Coram Experimental Forest in Montana. Comparative results are shown below:

Species	Falls Creek	Coram	Newman Ridge	Miller Creek
	Dispersal Ratio			
Engelmann spruce	~29	7	40	61
Western larch		14	9	19
Douglas-fir		12	12	6

Results from the four areas showed that dispersal ratios of spruce were more variable than those of larch or Douglas-fir. Spruce also appeared to have the potential of greater dispersal efficiency than any other species.

Seed soundness at Newman Ridge remained nearly constant in all zones up to 800 feet from the seed source. Percent soundness of seed was 26 percent, 25 percent, 22 percent, and 29 percent, respectively, in the zones 0-200 feet, 200-400 feet, 400-600 feet, and 600-800 feet from the timber.

Seed soundness for the good 1971 seed crop at Newman Ridge was higher than the average of the other five crops, but nearly the same as the 1971 crop at Miller Creek.

Area	Western larch	Douglas- fir	Engelmann spruce
	percent soundness		
Newman Ridge (all years except 1971)	4	11	18
Newman Ridge (1971)	15	39	45
Miller Creek (1971)	16	43	48

Seed germination. Total germination by aspect at Miller Creek ranked in the order north > southeast > southwest. No specific factors were positively identified as responsible for the high germination rate on the north aspect, or the lower rates on the southeast and southwest aspects. One possible explanation for this ranking is that a cool,

moist environment extended later into the spring on the north, due to retarded snowmelt. That cool, moist conditions persist about a week or ten days longer on the north may have a significant stratification effect on seed on this aspect. Heit (1972) found germination capacity of Douglas-fir seeds from Montana increased from 11-12 percent without stratification to 75-80 percent with moist prechilling. Though larch varies in dormancy, it too benefits from cool, moist stratification (Heit 1967). Engelmann spruce, however, does not require stratification for maximum germination. The decreasingly shorter period of time cool, moist conditions exist on the southeast and southwest slopes as compared to the north could account for the lower germination figures on these aspects.

Weekly observations of germination plots in the spring of 1968, 1970, and 1971 showed seeds germinating first on the southeast aspect, then the southwest, and finally on the north aspect. This is the same order that the three aspects became snowfree in the spring.

Initial germination of the different species varied from several days before snowmelt to approximately three weeks after. Western larch was the first species to germinate, with some seed noted germinating under the snow. Engelmann spruce, on the other hand, first germinated two or three weeks after snowmelt. All other species began germinating one or two days after the seedbed became snowfree. Germination usually reached its peak the week following snowmelt, then declined steadily and, with the exception of spruce, ended about four weeks later. Spruce continued to germinate at a low level throughout most of the summer.

Germination of artificially sown seed was greater on plots with little or no duff (0-0.5") than on plots with >0.5" duff. Difference in germination between the two seedbeds was greatest on the southeast aspect. As shown below, 64 percent of the total germination on that aspect occurred on 0-0.5" duff, and only 36 percent on seedbed with >0.5" duff.

Aspect	Percent germination by duff depth on three aspects	
	0-0.5"	>0.5"
North	56	44
Southeast	64	36
Southwest	52	48

Germination was also greater on the 0-0.5" seedbed on the north and southwest aspects. However, differences in germination between seedbeds on these two aspects were not as extreme as on the southeast.

Germination success of western larch and Engelmann spruce was highest on the north aspect, while Douglas-fir germinated in greatest numbers on the southeast aspect (Table 5). Larch sown on the north aspect derived the greatest viability advantage of any species on any aspect, with 46 percent of total larch germination occurring there. No significant differences in percent of total germination were noted between species on any aspect.

Germination success on different seedbeds varied considerably by species. Douglas-fir germinated equally well on seedbed with heavy duff as on those with little or no duff (Table 6). Germination of Engelmann spruce, on the other hand, was significantly greater on

seedbeds with little or no duff. Seedbed effects on larch germination were intermediate to those on Douglas-fir and Engelmann spruce.

Table 5.—Percent of total germination of each of three species on three aspects at Miller Creek (1968-1971)

Species	Germination		
	North	Southeast Percent	Southwest
Western larch	46	33	21
Douglas-fir	36	41	23
Engelmann spruce	40	37	23

Table 6.—Percent of total germination of each of three species on two seedbeds at Miller Creek (1968-1971)

Duff Depth	Germination		
	Western larch	Douglas-fir Percent	Engelmann spruce
0.0-0.5"	55	50	64
>0.5"	45	50	36

Germination of seeds sown on test plots at Newman Ridge was highest on the east aspect, followed by the north, south, and west slopes. That germination was greater on the east aspect than the north deviated from the Miller Creek findings, though differences in germination between the two slopes were not significant.

Weekly observations of germination plots in the spring of 1970, 1971, and 1972 showed south as the slope on which seeds first germinated, and north as the last. The relative ranking of initial germination on east and west aspects, other than falling between south and north, was not determined because of variable snowpack and accessibility problems.

Germination was higher on seedbed with little or no duff (0-0.5") than on seedbed with >0.5" duff on all aspects. Germination differences between the two types of seedbed were greatest on south slopes. On that aspect, 67 percent of the total germination occurred on plots with 0-0.5" duff, and only 33 percent on plots with >0.5" duff.

A similar, though less pronounced trend also existed on the other aspects, as shown below:

Aspect	Percent germination by duff depth on four aspects	
	0-0.5"	>0.5"
North	54	46
East	63	37
South	67	33
West	61	39

At Newman Ridge, germination by aspect of both western larch and Douglas-fir ranked in the order north > east > south > west (Table 7). Though germination was studied from 1970-1972, nearly all differences by aspect occurred in one year, 1971. Reasons for the significant differences in 1971 larch and Douglas-fir germination by aspect are not known. Since Engelmann spruce seed was sown on only one aspect (east),

comparisons of germination by aspect for this species could not be made.

Table 7.—Percent of total germination of each of two species on four aspects at Newman Ridge (1970-1972)

Species	Germination			
	North	East	South	West
	Percent			
Western larch	33	27	23	17
Douglas-fir	34	28	20	18

Western larch and Douglas-fir attained their greatest germination success on seedbed with little or no duff, as shown below:

Duff Depth	Germination (percent)	
	Western larch	Douglas-fir
0.0-0.5"	59	56
>0.5"	41	44

Engelmann spruce regenerated in too few numbers on the one aspect on which it was sown for meaningful comparisons to be made.

Seedling survival. Abiotic factors which were identified as significant causes of seedling mortality were solar radiation (high soil-surface temperatures) and drought. Solar radiation affected survival two

ways: (1) directly, by destroying cambial cells and girdling the hypocotyl at ground level, (2) indirectly, by heating and drying the soil. Clearcutting followed by prescribed burning removed most logging slash and nearly all vegetative cover, leaving the seedbed exposed to direct solar radiation. Resultant soil-surface temperatures of 79°C were measured on unshaded seedbed on south and west-facing slopes. First-year seedlings subjected to such intense temperatures suffered a high rate of mortality. Insolation losses were not serious on north slopes, as 55°C was the maximum temperature recorded on this aspect (Table 8). Insolation-caused death occurred primarily in July (Fig. 10).

Insufficient soil water in late summer due to evapotranspiration losses and low precipitation caused considerable seedling losses to drought on all aspects (Table 8). Most mortality due to drought occurred in August. Drought also acted in conjunction with frost in the spring and fall to cause further seedling mortality. Germinating seeds or first-year seedlings were occasionally lifted from the soil by frost and left with roots exposed to dessicate and die. Drought was the number one killer of seedlings on all aspects.

Two biotic factors, (1) bird and rodent predation, and (2) fungi caused severe seedling losses. In the spring of 1968 and prior to plot screening, over 90 percent of the germinants fell victim to nipping by migrating juncos. Screens were installed on plots in the fall of each of the following years, and removed after peak germination each spring. After screens were removed, seedling depredation by rodents and birds took place at a rather constant rate for the remainder of the summer (Fig. 10).

Figure 10.—Percent of total seedling mortality at Miller Creek caused by each of five factors and inclusive dates each was operative.

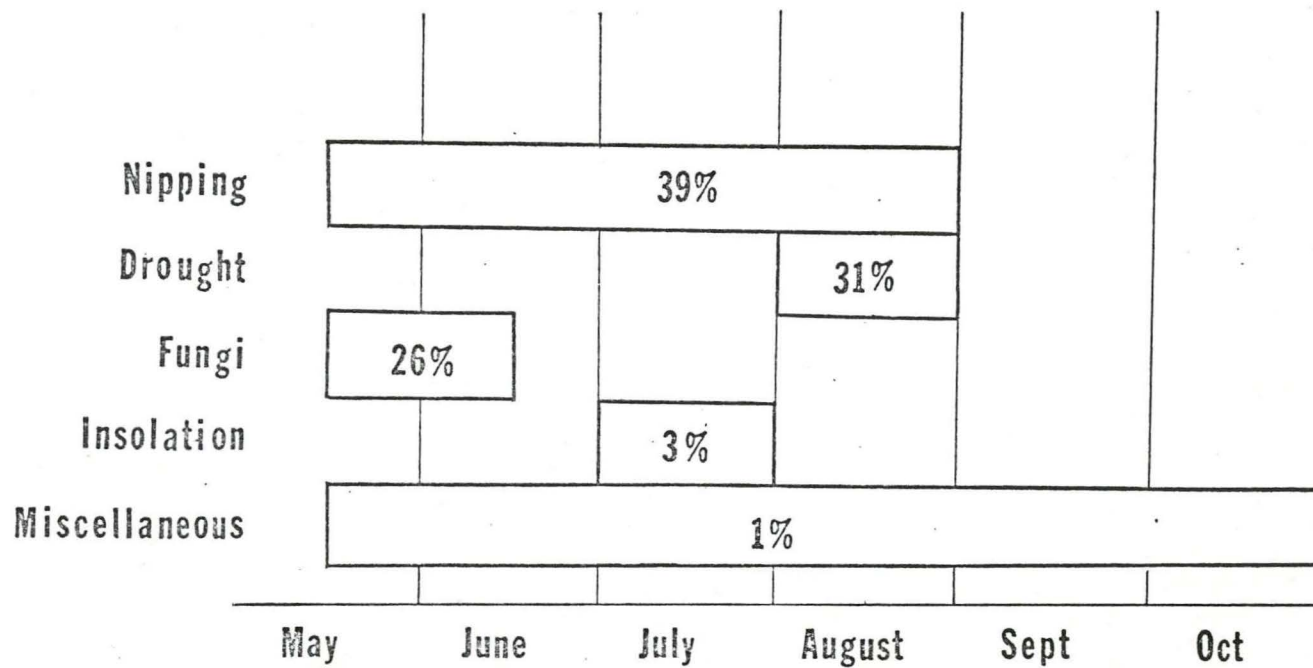


Table 8.—Seedling mortality by cause at Miller Creek
as percent of total germination on each aspect
(1970-1971)

Aspect	Cause of Mortality					Total
	Drought	Fungi	Nipped	Insol.	Misc.	
	Percent					
North	17	15	13	0	0	45
East	28	21	14	1	0	64
West	29	26	14	4	1	74

Fungi, especially damping-off fungi, also caused considerable seedling mortality from the time of germination in May until the spring wet period was over in late June (Fig. 10). Fungi was a greater problem on seedbed with >0.5" duff than on surfaces with little or no duff (Table 9). During moist periods, the high nitrogen and pH conditions in the duff layer combine with the high water content to provide favorable conditions for pith-feeding fungi. Such conditions make the duff layer a more desirable medium for fungal activity than mineral soil, and hence greater seedling mortality occurred there.

Seedling losses to miscellaneous factors were minor, and took place throughout the summer months (Fig. 10).

Mortality losses at Newman Ridge due to abiotic causes (solar insolation and drought) were highest on the south aspect, and lowest on the east. Though no insolation-related mortality was noted on the north aspect, a gradually increasing percentage of germinants was lost to insolation on the east, south, and west aspects (Table 10). Nearly all the seedling losses due to insolation occurred in June (Fig. 11).

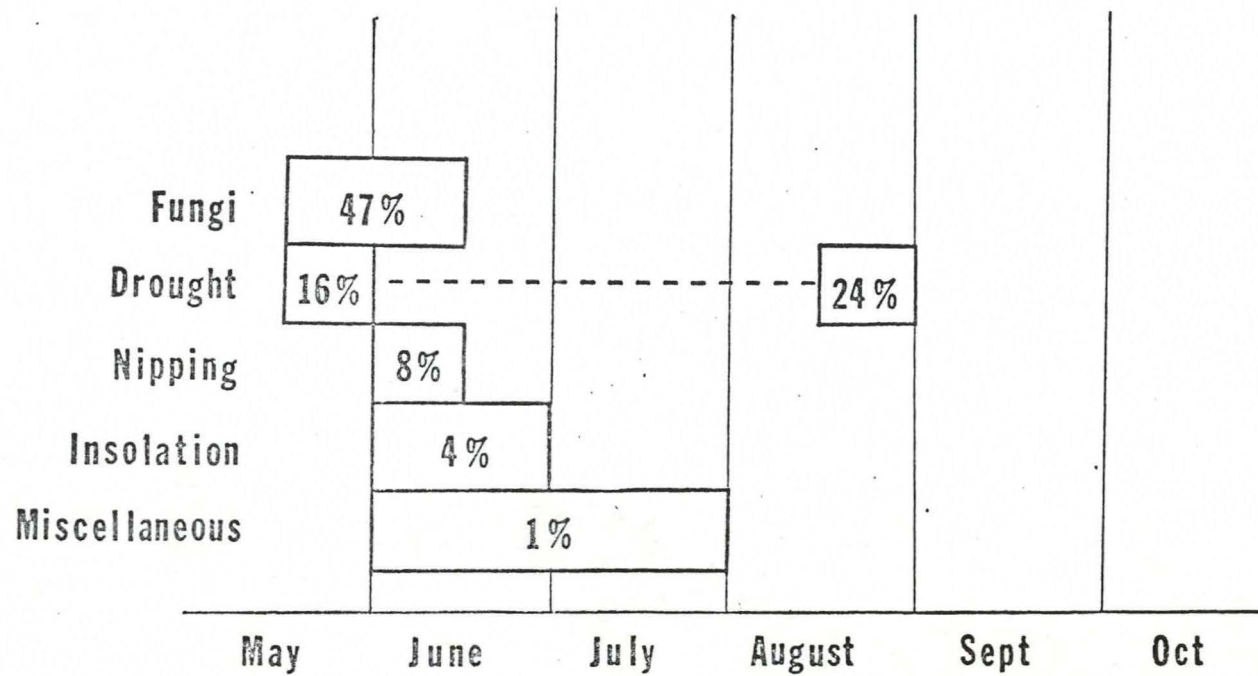
Table 9.—Seedling mortality by cause and duff depth
(1970-1971)

Cause of Mortality	Duff Depth			
	Miller Creek		Newman Ridge	
	0.0-0.5	>0.5	0.0-0.5	>0.5
	Percent			
Drought	20	18	23	31
Fungi	15	20	26	36
Nipped	15	12	5	6
Insolation	1	3	3	2
Miscellaneous	<u>1</u>	<u>1</u>	<u>1</u>	<u>1</u>
Total	52	54	58	76

Table 10.—Seedling mortality by cause at Newman Ridge
as percent of total germination on each aspect
(1970-1972)

Aspect	Cause of Mortality					Total
	Drought	Fungi	Nipped	Insol.	Misc.	
	Percent					
North	29	38	6	0	1	75
East	17	23	4	1	0	45
South	33	23	6	4	1	67
West	21	32	5	6	0	64

Figure 11.—Percent of total seedling mortality at Newman Ridge caused by each of five factors and inclusive dates each was operative.



Drought was the leading cause of seedling death on the south aspect, and the second most important cause on all other aspects (Table 10). Seedling losses to drought were unexpectedly high on the north aspect, and probably reflect data aberrations due to insufficient sampling, rather than actual conditions on the ground. Mortality figures on the north aspect were based on only one sampling unit, as the unit (N-3) on which the second replicate was to be installed was not burned as scheduled. Results for all other aspects were based on two replicates. Most drought-caused mortality showed up the last two weeks of May and again the last half of August.

Fungi was the primary cause of seedling mortality on all aspects except south, and was especially severe on the north and west aspects. This apparent high rate of seedling loss to fungi on the north aspect, as with drought, was probably due to insufficient sampling. Fungi caused higher mortality on seedbed with >0.5 " duff than on light duff (<0.5 ") or mineral seedbed (Table 9). Mortality resulting from fungal activity occurred from mid-May to mid-June (Fig. 11).

Nipping by birds and rodents took a minor toll of newly-germinated seedlings during the first half of June (Fig. 11). Seedling predation began immediately after screens were removed from the plots, continued for about two weeks, then ceased to be a problem for the remainder of the summer.

Miscellaneous factors caused an insignificant amount of mortality through June and July (Fig. 11).

Regeneration. Natural regeneration counts taken in fall 1973 and spring 1974 at Miller Creek showed the greatest number of seedlings per acre (3160) on Abies/Clintonia h.t. Clintonia phase and the highest stocking (76%) on Abies/Clintonia h.t. Menziesia phase (Table 11). Both western larch and Douglas-fir regenerated best on Abies/Clintonia h.t. Clintonia phase, while Engelmann spruce and subalpine fir regenerated in greatest numbers on Abies/Clintonia h.t. Menziesia phase. Seedlings per acre and percent stocking were both lowest on the Abies/Clintonia h.t. Xerophyllum phase.

Table 11.—Natural regeneration by species and habitat type at Miller Creek for period 1969-1973

Habitat Type	Seedlings per Acre						Stocking —percent—
	WL	DF	ES	AF	Other	Total	
A/C-M	261	552	1360	723	20	2916	76
A/C-C	1140	765	811	390	54	3160	60
A/C-X	569	513	180	335	199	1796	32

The moderate Abies/Clintonia h.t. Clintonia phase provided a favorable site for the germination and establishment of all Miller Creek species (Table 12). The drier Abies/Clintonia h.t. Xerophyllum phase favored regeneration by western larch and Douglas-fir, while the cool, moist Abies/Clintonia h.t. Menziesia phase favored regeneration of Engelmann spruce and subalpine fir.

Results of Newman Ridge regeneration surveys taken in 1972, 1973, and 1974 showed significant differences in the number of seedlings/acre

Table 12.—Natural regeneration by species as percent of total regeneration on each Miller Creek habitat type

Habitat Type	Species				
	WL	DF	ES percent	AF	Other
A/C-M	9	19	46	25	1
A/C-C	36	24	26	12	2
A/C-X	32	28	10	19	11

and percent stocking between habitat types. Seedlings/acre and percent stocking ranged from a low of 109 and 6 percent, respectively on *Pseudotsuga menziesii*/Xerophyllum h.t. Vaccinium phase, to a high of 2076 and 70 percent, respectively on *Thuja plicata*/Clintonia h.t. Menziesia phase (Table 13). If 40 percent stocking and 1000 seedlings/acre are lower limits for adequate stocking, natural regeneration was deficient on *Abies grandis*/Xerophyllum h.t., *Pseudotsuga menziesii*/Physocarpus h.t. Physocarpus phase, and *Pseudotsuga menziesii*/Xerophyllum h.t. Vaccinium phase. Lack of available water during critical periods was probably a major cause for the low regeneration success on these three habitat types.

Natural regeneration was most successful on mineral seedbed, and decreasingly less so on seedbed with 0.5" and >0.5" duff (Table 14). When causes of mortality were examined by seedbed, fungi was found to be a slightly greater problem on a duff surface than on mineral soil.

Five species regenerated an average of more than 100 seedlings/acre on Newman Ridge clearcuts. Of these, three species, western larch,

Table 13.—Natural regeneration at Newman Ridge by species and habitat type for the period 1970–1973

Species	Habitat Type				
	Seedlings per Acre				
	T/C	G/C	G/X	P/P	P/X
	number				
Western larch	97	45	51	6	0
Douglas-fir	809	285	188	85	34
Lodgepole pine	23	14	11	0	6
Ponderosa pine	181	97	27	341	57
Grand fir	909	451	51	6	11
Engelmann spruce	37	68	2	0	0
Western white pine	<u>20</u>	<u>0</u>	<u>1</u>	<u>0</u>	<u>0</u>
Total	2076	960	331	438	108

Table 14.—Natural regeneration by seedbed condition and habitat type at Newman Ridge for period 1970–1973

Habitat Type	0.0"	0.5"	>0.5"	Total	:	0.0"	0.5"	>0.5"	Total
	Seedlings per Acre				:	Percent Stocking			
T/C	2824	1981		2076	:	88	68		70
G/C	600	993		960	:	38	44		43
G/X	357	347		331	:	21	18	18	18
P/P	250	472	250	438	:	19	11		12
P/X	50	113		108	:	5	7		6

Douglas-fir, and grand fir regenerated in greatest numbers on *Thuja plicata*/Clintonia h.t. Menziesia phase (Table 13).

Natural regeneration was most successful on north-facing clear-cuts, decreasing as the cutting units faced more southerly directions. A striking example of the effect of aspect on regeneration occurred on unit E-3, whose subunits 1, 2, and 3 had azimuths of 96° , 110° and 141° respectively. Corresponding regeneration figures for these subunits were 1400, 865, and 516 seedlings per acre, and 50, 45, and 32 percent stocking.

Seed:seedling ratios developed for Newman Ridge habitat types point to regeneration problems for all types except *Thuja plicata*/Clintonia uniflora h.t. Menziesia ferruginea phase and *Abies grandis*/Clintonia uniflora h.t. (Table 15). Ratios were derived using data from the good 1971 seed crop and the next year's (1972) natural regeneration survey. *Pseudotsuga menziesii*/Physocarpus h.t. Physocarpus phase, *Abies grandis*/Xerophyllum tenax h.t., and *Pseudotsuga menziesii*/Xerophyllum h.t. Vaccinium phase received 25,000, 23,000, and 28,000 seeds per acre, respectively, from the 1971 seed crop, yet required approximately 40,000, 60,000, and 200,000 seeds per acre, respectively, to achieve adequate regeneration (~ 1000 seedlings per acre). Results indicate that *Abies grandis*/Clintonia h.t. was adequately regenerated, and that *Thuja plicata*/Clintonia h.t. Menziesia phase was slightly overstocked after the good 1971 seed crop.

Seed:seedling ratios were developed for those species at Newman Ridge which dispersed seed in significant amounts. Interestingly, seed:seedling ratios appeared inversely related to seed weight, i.e. the

Table 15.—Seed:seedling ratios by habitat type at Newman Ridge and approximate seeds per acre needed for adequate regeneration of these types

Habitat Type	Seed:Seedling Ratio	Seeds per Acre —number—
T/C	6:1	~6,000
G/C	17:1	~17,000
P/P	41:1	~41,000
G/X	57:1	~57,000
P/X	214:1	~214,000

heavier-seeded species had low seed:seedling ratios, and the light-seeded species high ratios, as shown below:

Species	Cleaned Seeds per Pound	Seed:Seedling Ratio
Ponderosa pine	~12,000	11:1
Grand fir	~19,000	16:1
Douglas-fir	~40,000	44:1
Western larch	~135,000	53:1
Engelmann spruce	~135,000	74:1

Planting Stock

Planting stock at Miller Creek showed no significant difference in the percent of seedlings surviving or with good vigor for any species on any habitat type (Table 16). Furthermore, when all species were analyzed in combination, survival and vigor of seedlings were nearly equal on all habitat types over the four-year planting and examination period (1970-1973). All three phases of the *Abies lasiocarpa*/*Clintonia*

Table 16.—Survival and vigor of planting stock at Miller Creek by species and habitat type

Habitat Type	Western larch		Douglas-fir		Engelmann spruce		All Species	
	Good Vigor	Survival	Good Vigor	Survival	Good Vigor	Survival	Good Vigor	Survival
	percent							
A/C-X	51	53	54	54	70	72	58	59
A/C-C	58	61	56	59	70	75	62	65
A/C-M	54	58	58	64	70	78	60	67

uniflora h.t. (*Xerophyllum tenax*, *Clintonia uniflora*, and *Menziesia ferruginea* phase) provided sites equally conducive to survival of planted stock. Most mortality was probably due to storage problems prior to planting, rather than to severe conditions on a given site.

Newman Ridge, in contrast, exhibited distinct differences in seedling survival by habitat type. Stock planted on the *Thuja plicata*/*Clintonia* h.t. *Menziesia* phase had a higher percentage of seedlings surviving and with good vigor than stock planted on any other habitat type. *Pseudotsuga menziesii*/*Physocarpus* h.t. *Physocarpus* phase and *Pseudotsuga menziesii*/*Xerophyllum* h.t. *Vaccinium* phase were habitat types with the lowest percent survival, and the lowest percent good vigor seedlings, respectively (Table 17).

The percent of trees in good vigor and percent survival by habitat type was nearly the same for the 1970 and 1971 plantings. However, percent survival and percent good vigor seedlings decreased in 1972 on all habitat types except *Thuja*/*Clintonia* h.t. *Menziesia* phase (Table 1). Whatever factors effected a decrease in survival and vigor of stock on

Table 17.—Survival and vigor of planting stock at Newman Ridge by species and habitat type

Habitat Type	Western larch		Douglas-fir		Lodgepole pine		All Species	
	Good	Survival	Good	Survival	Good	Survival	Good	Survival
	Vigor		Vigor		Vigor		Vigor	
percent								
T/C	58	81	94	96	92	94	81	90
G/C	45	66	76	90	85	90	69	82
G/X	49	55	80	91	75	86	68	77
P/X	48	59	79	92	45	90	57	80
P/P	43	47	83	87	60	74	62	69

Table 18.—First-year evaluation of planting stock survival and vigor by habitat type at Newman Ridge

Habitat Type	Year Planted	Good Vigor	Survival
		percent	
T/C	70	84	88
	71	79	81
	72	82	92
G/C	70	68	82
	72	46	74
G/X	70	76	86
	71	70	79
	72	52	68
P/X	70	78	86
	71	76	95
	72	33	55
P/P	70	68	74
	—	—	—

other habitat types had no noticeable effect on plantings in this type. Since stock from the same lot was planted on all habitat types, it is doubtful that increases in mortality on a given type were due to variation in the condition of the planting stock. The Thuja/Clintonia h.t. Menziesia phase may well be a sufficiently good site that minor changes in microsite condition or planting stock had little effect on seedling survival.

The greatest increase in mortality in 1972 occurred on the Pseudotsuga/Xerophyllum h.t. Vaccinium phase (Table 18). From the standpoint of seedling survival, this was the most severe type studied in 1972 (Pseudotsuga/Physocarpus h.t. Physocarpus phase not planted in 1971 and 1972). Therefore, even small adverse changes in site factors (decreased precipitation, higher insolation) or planting stock condition on this type could easily upset what is normally only marginal conditions for survival and growth. Changes in vigor and survival of planted seedlings on other habitat types were between those of the Thuja/Clintonia h.t. Menziesia phase (no change) and the Pseudotsuga/Xerophyllum h.t. Vaccinium phase (significant change).

Looking at planting success from a species standpoint, the uniform but low survival rate of western larch was probably due to the rather poor condition of the stock even before planting. Though Engelmann spruce had a somewhat higher survival rate than larch, it was lower than expected. Reasons for the significant mortality rate in spruce were less evident than for larch. However, spruce was planted on all three East-3 subunits, and was quite probably off-site in subunits 2 and 3. Unit E-3

was somewhat concave, contouring from an east-facing subunit (1), to generally southeast-facing subunits (2 and 3). Subunits 2 and 3 are drier, and may be severe enough to preclude a high survival rate in spruce plantings.

IMPLICATIONS

Prescribed Burning

Timing

Timing of prescribed broadcast burning to achieve adequate site preparation proved to be more important than the fact of burning. Burns conducted in the spring or early summer when the large fuels and duff layer were near saturation were of low intensity, and caused little duff reduction. Once dry, considerable precipitation was required to resaturate large fuels and duff. Only a brief drying period was required after heavy summer or early fall precipitation before burning was again effective in exposing some mineral soil.

Conditions under which north slopes can be burned to substantially reduce the duff layer occur only infrequently. Days which meet these requirements would usually occur in August. Considerably more days occur each summer and fall for broadcast burning slash on other aspects to achieve adequate site preparation.

Intensity

High intensity burns are neither necessary nor desirable on favorable habitat types. Such burns expose mineral soil on a high proportion of the surface area, and overstocking may result. If overstocking occurs, costly precommercial thinning may be necessary to remedy the problem.

Moderate intensity fires generated enough heat to dry and consume most of the duff layer on Newman Ridge clearcuts. Fires of similar

intensity on Miller Creek clearcuts consumed only moderate amounts of duff. Because the average duff depth at Newman Ridge was less than at Miller Creek, moderate intensity burning was considerably more efficient at reducing the duff layer there.

Effect on Soil

Prescribed broadcast burning had minimal effects on soil composition, as indirectly measured by soil water samples and root mortality counts. Soil water samples taken immediately before and after burning, and then periodically for several years, showed no significant burning effects on the water-holding capacity of the soil. Most root mortality due to burning was confined to the surface one-inch of soil, indicating little harmful heating below that level. The insignificant effect of prescribed broadcast burning on soil characteristics may not be true for dozer piling and burning of slash.

Indirect Effects

Prescribed broadcast burning of slash on clearcuts results in debris scattered randomly throughout the area. Charred debris, although unsightly, offers site protection which is beneficial to conifer establishment on exposed south and west slopes. However, this factor decreases in importance as the slope becomes more protected (east, northwest, and north aspects).

Regeneration Systems

Larch-fir stands on *Abies lasiocarpa*/*Clintonia* h.t. *Clintonia* phase and *Abies lasiocarpa*/*Clintonia* h.t. *Menziesia* phase can be adequately

regenerated when certain criteria are met: (1) cutting units are limited to 10 acres in size, (2) seedbed preparation is accomplished by prescribed broadcast burning, and (3) each unit has at least two seedwalls. However, clearcuts meeting the above criteria on steep slopes in the *Abies lasiocarpa*/*Clintonia* h.t. *Xerophyllum* phase were not adequately regenerated five years after logging. Seedbed surface temperatures as high as 175°F were recorded on south and west-facing slopes. These high temperatures manifest the need of keeping some protection on exposed sites. For this reason, the shelterwood system is recommended for steep south and west aspects in the *Abies lasiocarpa*/*Clintonia* h.t. *Xerophyllum* phase if adequate natural regeneration is to be obtained soon after logging. Stands on this habitat type were comprised primarily of western larch and Douglas-fir, with some encroaching subalpine fir. No more than 60 percent of the volume in these stands would be removed in the initial cutting, leaving ample larch and Douglas-fir as seed source and site protection for regenerating a new stand. Seedbed preparation after logging would be accomplished by broadcast burning the slash as it lies. All subalpine fir would either be removed in harvest, or felled and slashed, as this species is easily damaged by fire, and could also act as a mode of transport for fire to reach the crowns of dominant larch and Douglas-fir in the residual stand.

Clearcutting a stand may be the only management alternative in some cases, due to a single outside factor, such as insect or disease epidemics. Planting may then be the only way to regenerate these sites, or those burned in wildfires. If regeneration is accomplished by planting, augers should be used to ensure straight root systems in the planted stock.

Seed Dispersal

Timing

Seed crops of larch-fir stands on upper slopes at Newman Ridge disperse seed in early to mid-October, some two weeks to nearly a month later than those on the lower slopes or valley bottoms. Seed dispersal on the Newman Ridge clearcuts also began three to four weeks later than on Miller Creek units. This late dispersal of seed gives the manager an opportunity to prescribe burn upper slope cutovers after the summer drought period is over, and still accomplish site preparation before seed is dispersed in early October. Conversely, burning slash on lower slopes or valley bottoms after fall rains have begun may result in a majority of the year's seed crop, which has already been dispersed, going up in smoke.

Distance

The central area of large clearcuts in mixed stands will tend to be seeded by the lighter-seeded species in the seedwall. Clearcuts at both Newman Ridge and Miller Creek were made in stands comprised of a species admixture. The central area in these clearcuts beyond about 300 feet from the timber tended to be seeded by the light-seeded species, i.e. western larch and Engelmann spruce. If this situation is considered a problem, two options are available to the manager. The preventative option would be planning clearcuts which correspond in size to the dispersal limits of desired species. The remedial approach would be to plant the core area of larger clearcuts with preferred species.

Seed:Seedling Ratios

A potential problem area related to both seed dispersal and site quality involves widely variable seed:seedling ratios by habitat type. For example, on the mesic *Thuja plicata*/*Clintonia* h.t. *Menziesia* phase at Newman Ridge, seedlings per acre and percent stocking were well above the rule-of-thumb limits of 1000 and 50, respectively, for adequate regeneration. However, the dry *Pseudotsuga menziesii*/*Xerophyllum* h.t. *Vaccinium* phase received more than twice as much seed per unit area as the *Thuja plicata*/*Clintonia* h.t. *Menziesia* phase, yet regeneration on this type was grossly inadequate, with only 100 seedlings per acre and 5 percent stocking. This on-the-ground evidence supports the hypothesis that seed dispersal may not be relied upon to adequately regenerate clearcuts on dry sites generally, or beyond the point where seed dispersal levels off, specifically (~300 feet from the seedwall).

Germination and Survival

Germination of seed is enhanced on seedbed with little or no duff (0.0-0.5"). Western larch, Douglas-fir, and Engelmann spruce all germinated in greater numbers on seedbed with 0.0-0.5" duff, than on seedbed with >0.5: duff. Engelmann spruce derived the greatest germination benefit from bare or nearly bare seedbed, and Douglas-fir the least. Duff depth >0.5" appeared to have a stronger adverse effect on germination on the severe sites at Newman Ridge than on the more moderate Miller Creek sites. Subsequent seedling survival, as with germination, was also greater at both areas on seedbed with little or no duff. Seedling survival on >0.5" duff seedbed was lower at Newman Ridge than on the more mesic Miller Creek sites.

Natural Regeneration

Natural regeneration potentials of the eight habitat types encountered on the two study areas varied significantly. This variability points to the need by management for guidelines concerning expected natural regeneration success by habitat type. Clearcuts on only three of the eight habitat types surveyed could be relied on to regenerate adequately (50 percent stocking, 1000 seedlings/acre) by natural means (Table 19). Conversely, clearcuts on three others could not be expected to regenerate successfully without outside help (i.e. direct seeding or planting), and the regeneration chances of the remaining two types were questionable.

Table 19.—Expected natural regeneration potential of Miller Creek and Newman Ridge clearcuts by habitat type

Habitat Type	Study Area	Seedlings Per Acre (number)	Stocking (percent)	Natural Regeneration Potential
A/C-M	Miller Creek	2916	76	Good
A/C-C	Miller Creek	3160	60	Good
A/C-X	Miller Creek	1796	32	Fair
T/C	Newman Ridge	2076	70	Good
G/C	Newman Ridge	960	43	Fair-Good
G/X	Newman Ridge	331	18	Poor
P/P	Newman Ridge	438	12	Poor
P/X	Newman Ridge	108	6	Poor

Direct Seeding

The degree of site preparation accomplished by prescribed burning on most units at Newman Ridge and Miller Creek would make direct seeding

a viable alternative if natural dispersal failed. This method would give the manager some control over species competition, stocking, and the number of seed applied to a given habitat type.

Planting

Expected planting success would be nearly equal on any of the three phases (Xerophyllum, Clintonia, or Menziesia) of the Abies lasiocarpa/Clintonia h.t. at Miller Creek. No significant difference was noted in the percent of western larch, Douglas-fir, or lodgepole pine seedlings surviving or with good vigor on any habitat type.

However, at Newman Ridge, considerable differences exist in expected planting success by habitat type for most species, as shown in Table 20. This table provides a relative ranking of expected planting success by habitat type. Of the five species studied, only ponderosa pine survived equally well on all of the habitat types on which it was planted.

Table 20.—Expected planting success by habitat type
for five species at Newman Ridge

Species	Survival by Habitat Type				
Western larch	T/C	>	G/C P/X G/X	>	P/P
Douglas-fir	T/C	>	P/X G/X G/C	>	P/P
Lodgepole pine	T/C	>	G/C P/X G/X	>	P/P
Grand fir	T/C	>	G/C G/X		
Ponderosa pine	P/P P/X G/X				

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APPENDIX A: TREATMENT AND SAMPLING SCHEDULES

Miller Creek

Unit	Date Burned	Habitat Type	Soil H ₂ O	Soil Temperature	Root Mortality	Duff Reduction	Seedbed Evaluation	Natural Regeneration
N 1	Control	Abla/Clun-Clun	X					
N 2	Control	Abla/Clun-Clun						
N 3	Control	Abla/Clun-Clun						
N 4	8/31/68	Abla/Clun-Mefe		X		X	X	X
N 5	10/9/67	Abla/Clun-Mefe			X		X	X
N 6	9/10/68	Abla/Clun-Mefe						
N 7	6/18/68	Abla/Clun-Mefe	X	X	X	X	X	X
N 8	9/10/68	Abla/Clun-Mefe	X	X	X	X	X	X
N 9	7/26/68	Abla/Clun-Mefe	X	X	X	X	X	X
N10	Control	Abla/Clun-Mefe						
N11	8/3/67	Abla/Clun-Mefe	X	X	X	X	X	X
N12	8/3/67	Abla/Clun-Mefe						
N13	7/8/68	Abla/Clun-Mefe	X	X	X	X	X	X
N14	10/3/68	Abla/Clun-Mefe						
N15	10/3/68	Abla/Clun-Mefe						
E 1	10/10/67	Abla/Clun-Clun						
E 2	Control	Abla/Clun-Mefe	X					
E 3	8/7/68	Abla/Clun-Mefe	X	X	X	X	X	X
E 4	7/18/68	Abla/Clun-Mefe						
E 5	7/5/68	Abla/Clun-Mefe	X	X	X	X	X	X
E 6	10/2/67	Abla/Clun-Clun	X	X	X	X	X	X
E 7	7/18/67	Abla/Clun-Clun	X	X	X	X	X	X
E 8	10/1/70	Abla/Clun-Clun						
E 9	10/1/70	Abla/Clun-Clun						
E10	9/9/68	Abla/Clun-Clun	X	X	X	X	X	X
E11	8/23/67	Abla/Clun-Clun	X				X	X
E12	8/23/67	Abla/Clun-Clun					X	X
E13	8/23/67	Abla/Clun-Clun	X	X	X	X	X	X
E14	9/9/68	Abla/Clun-Clun						
E15	7/18/67	Abla/Clun-Clun						
S 1	5/18/68	Abla/Clun-Xete					X	X
S 2	5/18/68	Abla/Clun-Xete					X	X
S 3	5/18/68	Abla/Clun-Xete	X					
S 4	7/3/68	Abla/Clun-Xete		X	X	X	X	X
S 5	9/30/68	Abla/Clun-Xete						
S 6	8/23/67	Abla/Clun-Xete						
S 7	8/23/67	Abla/Clun-Xete	X		X			
S 8	8/8/67	Abla/Clun-Xete	X	X	X	X	X	X
S 9	10/5/67	Abla/Clun-Xete	X	X	X	X	X	X
S10	7/3/68	Abla/Clun-Xete	X	X	X	X	X	X
S11	Control	Abla/Clun-Xete						
S12	8/23/67	Abla/Clun-Xete					X	X
S13	8/23/67	Abla/Clun-Xete					X	X
S14	8/23/67	Abla/Clun-Xete						
S15	8/23/67	Abla/Clun-Xete						
W 1	7/25/67	Abla/Clun-Clun	X	X	X	X	X	X
W 2	8/23/67	Abla/Clun-Xete	X		X			
W 3	9/30/68	Abla/Clun-Xete						
W 4	9/5/68	Abla/Clun-Xete	X	X	X	X	X	X
W 5	8/23/67	Abla/Clun-Xete	X		X			
W 6	8/23/67	Abla/Clun-Xete	X					
W 7	8/23/67	Abla/Clun-Xete	X		X			
W 8	7/24/68	Abla/Clun-Xete	X	X	X	X	X	X
W 9	10/7/67	Abla/Clun-Clun		X	X	X	X	X
W10	7/16/68	Abla/Clun-Xete	X	X	X	X	X	X
W11	6/6/68	Abla/Clun-Clun						
W12	8/30/68	Abla/Clun-Clun	X	X	X	X	X	X
W13	8/30/68	Abla/Clun-Clun	X	X		X	X	X
W14	10/2/68	Abla/Clun-Clun	X					
W15	10/2/68	Abla/Clun-Clun						

Newman Ridge

Unit	Date Burned	Habitat Type	Soil H ₂ O	Soil Temperature	Root Mortality	Duff Reduction	Seedbed Evaluation	Natural Regeneration
N 1	7/14/69	Thpl/Clun-Mefe	X	X	X	X	X	X
N 2	7/25/69	Thpl/Clun-Mefe	X	X	X	X		
N 3	9/29/70	Thpl/Clun-Mefe	X				X	X
N 4	—	Thpl/Clun-Mefe						
E 1	7/9/69	Abgr/Xete	X	X	X	X	X	X
E 2	7/25/69	Thpl/Clun-Mefe	X	X	X	X		
E 3	7/25/69	Abgr/Clun	X		X		X	X
E 4	7/25/69	Thpl/Clun-Mefe						
S 1	6/4/69	Psme/Xete-Vagl	X	X	X	X	X	X
S 2	7/16/69	Abgr/Xete	X	X	X	X		
S 3	9/15/70	Psme/Xete-Vagl	X	X	X	X	X	X
S 4	—	Abgr/Clun						
W 1	6/1/69	Abgr/Xete	X	X	X	X	X	X
W 2	7/18/69	Abgr/Clun	X	X	X	X		
W 3	9/28/70	Abgr/Xete	X	X	X	X	X	X
W 4	9/29/70	Abgr/Xete						

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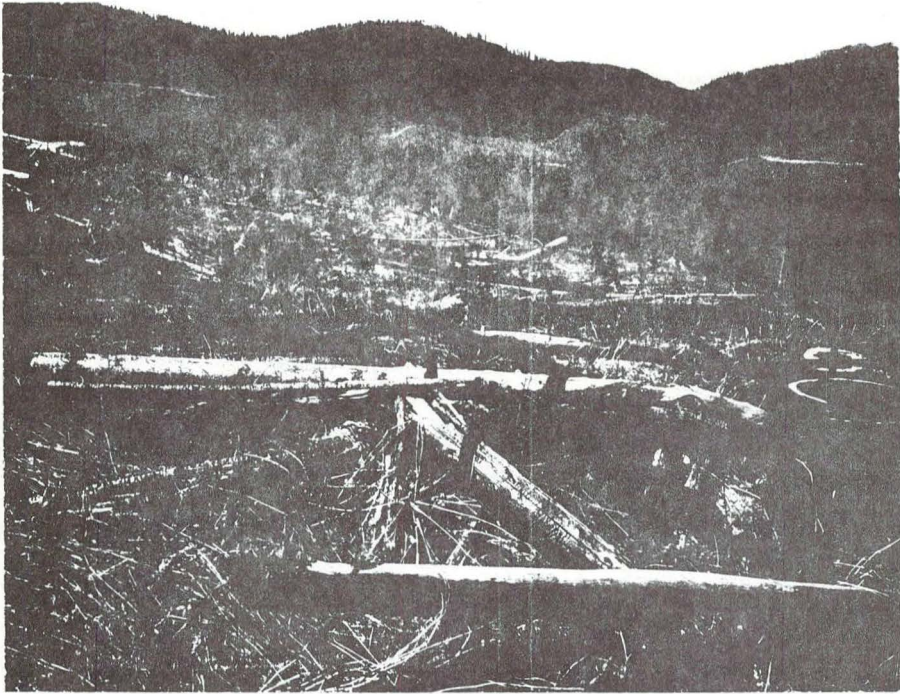


Plate 1.--Upper portion of unit N-11, Miller Creek, Flathead National Forest, Montana. Cut in 1966, slash burned 3 August 1967, picture taken 7 June 1971. Background clearcuts: upper left, portions of S-9, S-3, S-2, and S-1; upper center E-6 and S-11; upper right W-8. All clearcuts at Miller Creek are approximately 10 acres in area.

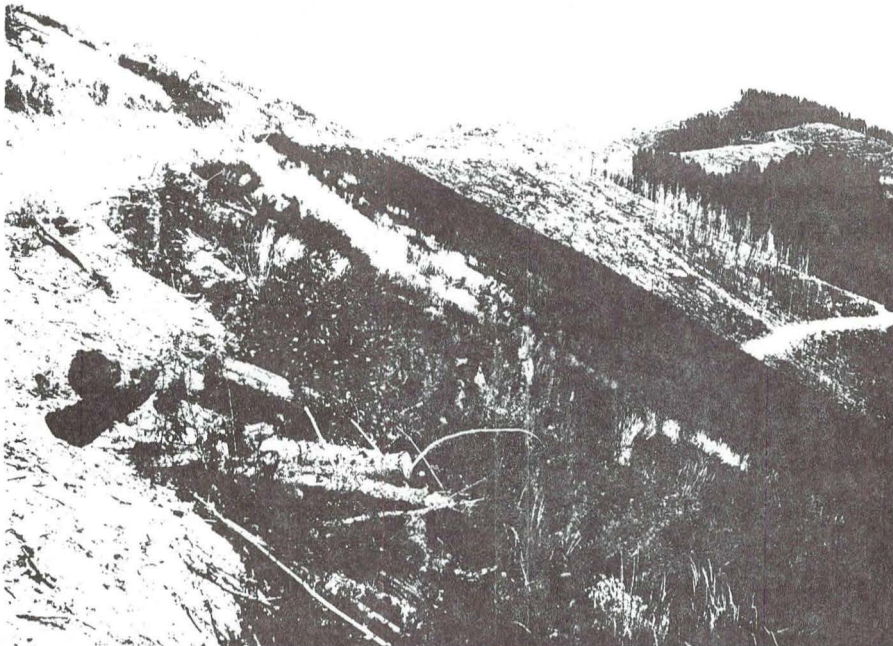


Plate 2.--Unit E-1, Newman Ridge, Lolo National Forest. Cut in 1968, slash burned 9 July 1969, picture taken August 1971. This clearcut is about 21 acres in area, others at Newman Ridge vary from 21 to 58 acres.



Plate 3.--Burying recorders in soil under slash to monitor changes in soil temperature during the prescribed broadcast burn on unit N-11, 3 August 1967, Miller Creek, Flathead National Forest.



Plate 4.--Taking soil samples for gravimetric determination of soil water on unit W-7, a hot, dry west-facing slope at Miller Creek, Flathead National Forest, 7 June 1971. This area burned during the wildfire of 23 August 1967, Miller Creek, Flathead National Forest.

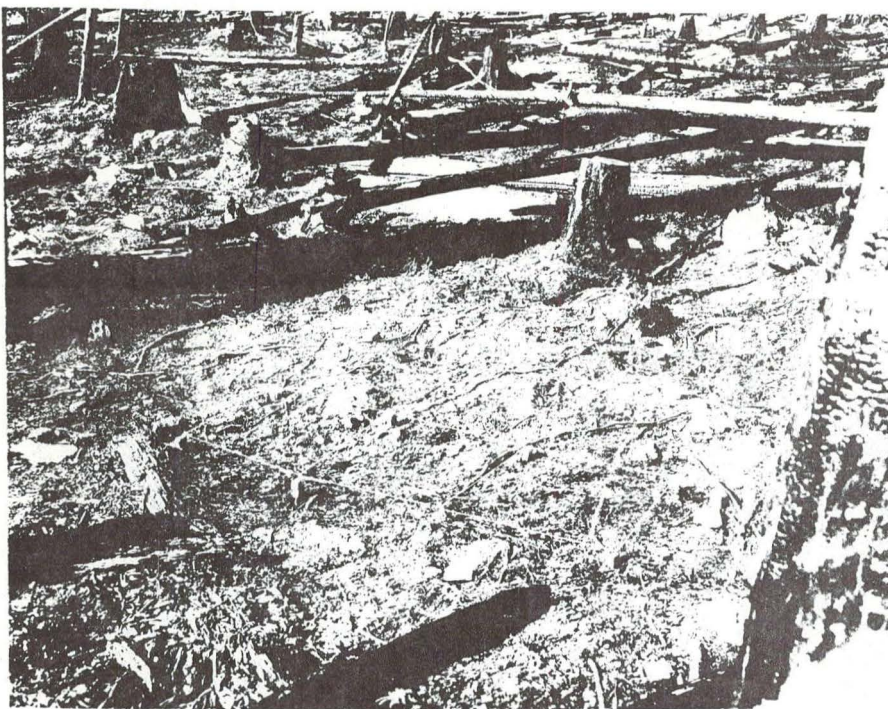


Plate 5.--Typical plot layout where seeds of western larch, Douglas-fir, and Engelmann spruce were sown in the fall and germination and seedling survival were monitored beginning the next spring. Unit W-1, burned 25 July 1967. Miller Creek, Flathead National Forest.

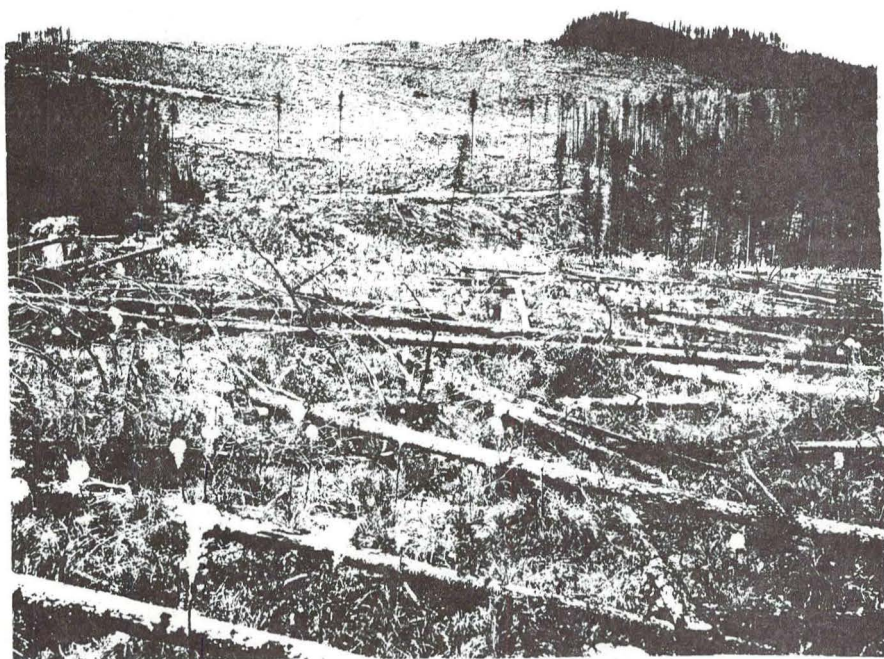
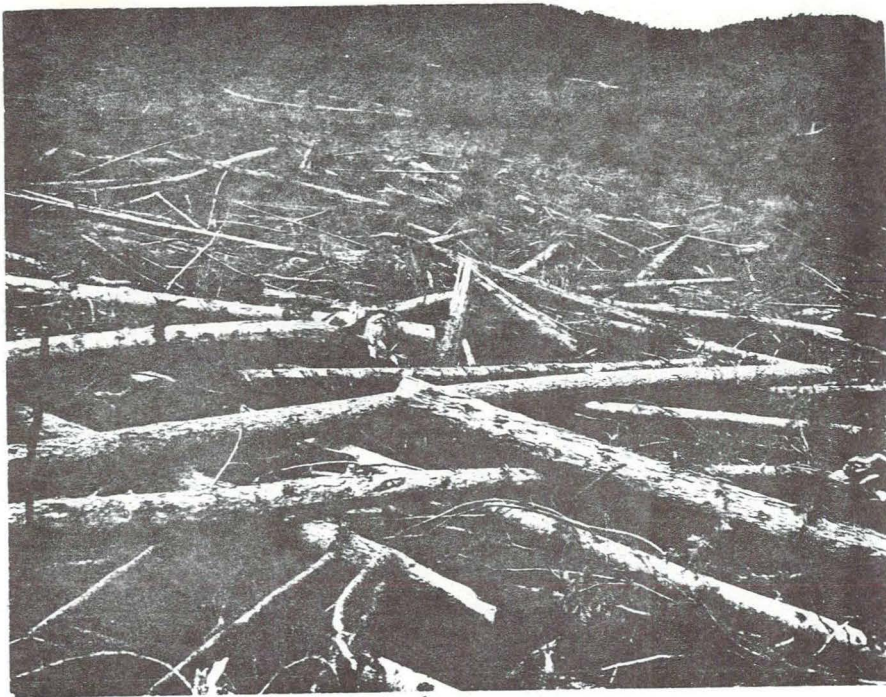


Plate 6.--Unit W-4 (foreground), small proportion of slash and duff burned on 5 September 1968. Although uncut timber bordered over two sides of the 10-acre clearcut an average of only 463 seedlings per acre were counted in the spring of 1974 and 22 percent of the milacre sample plots were stocked. In contrast unit E-7 (upper left), burned 18 July 1967 and reburned 23 August 1967 during the wildfire with no nearby seed source left after the wildfire had an average of 762 seedlings per acre and 52 percent of the milacre sample plots stocked. Miller Creek, Flathead National Forest.



A

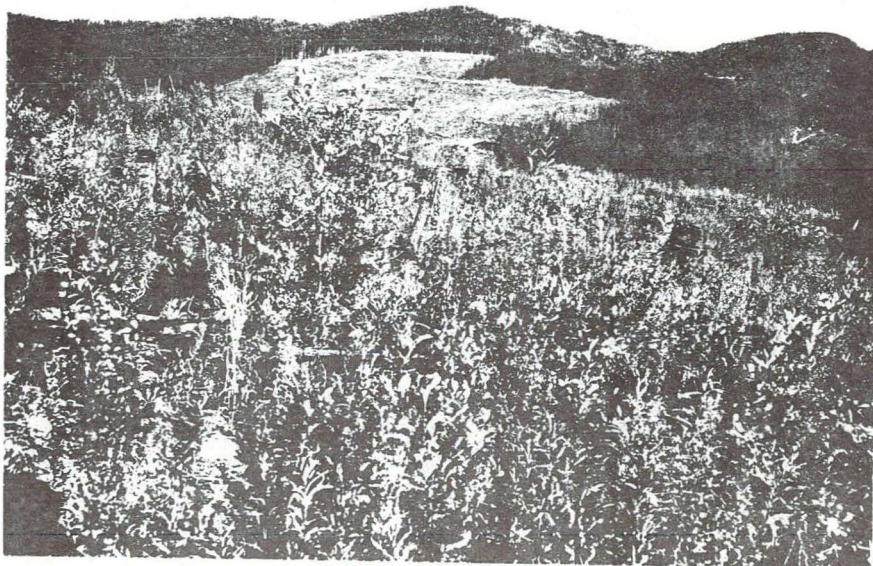


B

Plate 7.--Unit N-11, Miller Creek, Flathead National Forest. This 10-acre clearcut harvested in 1966 leaving seed source adjacent to two sides; slash prescribed broadcast burned 3 August 1967.

- (A) Unburned slash on 27 July 1967.
- (B) Fifteen days after burning, 18 August 1967.
- (C) In the spring of 1974, this area had 1729 seedlings per acre and 76 percent of the milacre sample plots were stocked.

Photographed 12 September 1975.



C

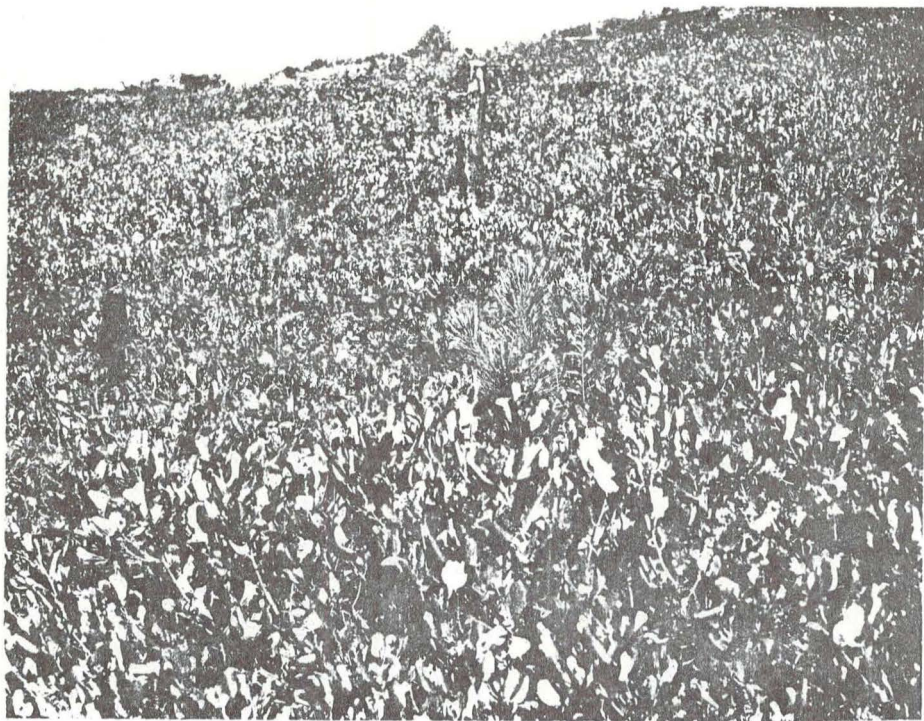


Plate 8.--Unit S-1, Newman Ridge, Lolo National Forest, planted ponderosa pine growing within evergreen ceanothus, September 1975.